Semi-Automatic Classification Plugin Documentation

Release 4.8.0.1

Luca Congedo

October 29, 2015

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Written by Luca Congedo, the **Semi-Automatic Classification Plugin** (SCP) is a free open source plugin for QGIS that allows for the **semi-automatic classification** (also supervised classification) of remote sensing images. Also, it provides several tools for the pre processing of images, the post processing of classifications, and the raster calculation.

SCP allows for the rapid creation of **ROIs** (training areas), through **region growing** algorithm, which are stored in a shapefile. The **scatter plot** or ROIs is available. Spectral signatures of training areas are calculated automatically, and can be displayed in a **spectral signature plot** along with the values thereof. Spectral distances among signatures (e.g. Jeffries Matusita distance, or spectral angle) can be calculated for assessing **spectral separability**. Spectral signatures can be exported and imported from external sources. Also, a tool allows for the selection and **download of spectral signatures** from the USGS Spectral Library .

SCP implements a tool for **searching and downloading Landsat and Sentinel** images. The following tools are available for the **pre processing** of images: **automatic Landsat conversion to surface reflectance**, **clipping** multiple rasters, and **splitting** multi-band rasters.

The **classification algorithms** available are: Minimum Distance, Maximum Likelihood, Spectral Angle Mapping. SCP allows for interactive **preview of classification**.

The **post processing** tools include: **accuracy assessment**, land cover change, classification report, classification to vector, reclassification of raster values. Also, a band calc tool allows for the **raster calculation** using NumPy functions .

For more information and tutorials visit the official site From GIS to Remote Sensing.

How to cite:

Congedo Luca, Munafo' Michele, Macchi Silvia (2013). "Investigating the Relationship between Land Cover and Vulnerability to Climate Change in Dar es Salaam". Working Paper, Rome: Sapienza University. Available at: http://www.planning4adaptation.eu/Docs/papers/08_NWP-DoM_for_LCC_in_Dar_using_Landsat_Imagery.pdf

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```
Semi-Automatic Classification Plugin is free software:  you can
redistribute it and/or modify it under the terms of the GNU General Public
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hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
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See the GNU General Public License for more details.  You should have
received a copy of the GNU General Public License along with Semi-Automatic
Classification Plugin.  If not, see http://www.gnu.org/licenses/.

The first version of the Semi-Automatic Classification Plugin was written
by Luca Congedo for the Adapting to Climate Change in Coastal Dar es Salaam
Project (http://www.planning4adaptation.eu).
```

Part I

Plugin Installation

The Semi-Automatic Classification Plugin requires the installation of GDAL, OGR, NumPy, SciPy and Matplotlib.

This chapter describes the installation of the Semi-Automatic Classification Plugin for the supported Operating Systems.

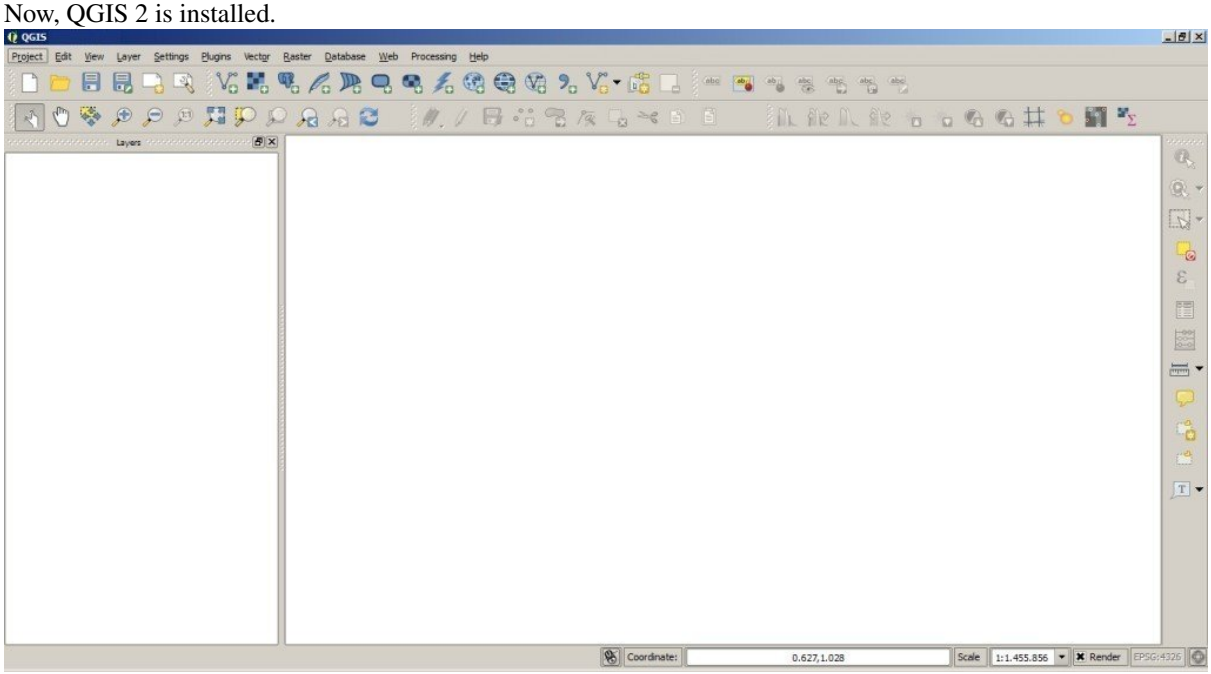
CHAPTER 1

Installation in Windows 32 bit

1.1 QGIS download and installation

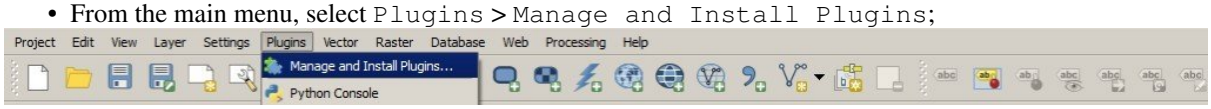
- Download the latest QGIS version 32 bit from here (the direct download of QGIS 2.8 from this link);
- Execute the QGIS installer with administrative rights, accepting the default configuration.

Now, QGIS 2 is installed.

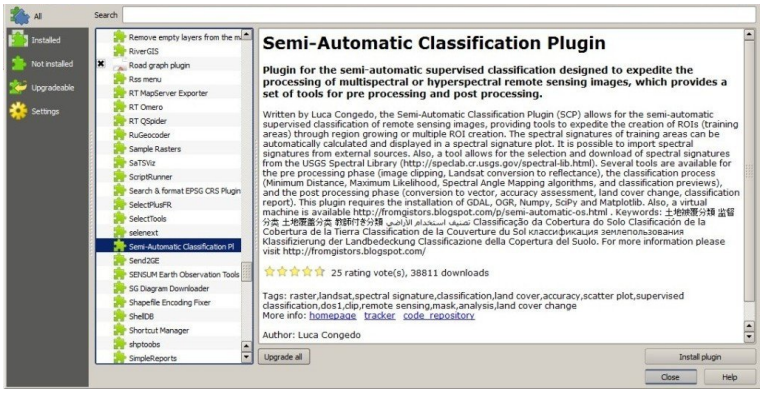


1.2 Semi-Automatic Classification Plugin installation

- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;


Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Help
Manage and Install Plugins...
Python Console

- From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;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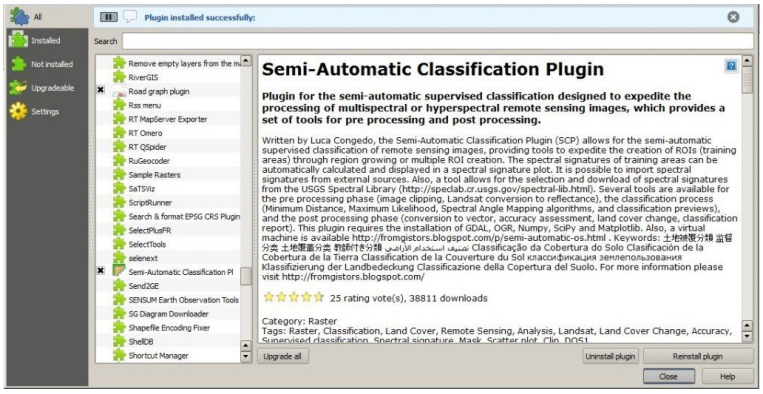
25 rating vote(s), 38811 downloads
Tags: raster,landsat,spectral signature,classification,land cover,accuracy,scatter plot,supervised classification,dos1,clip,remote sensing,mask,analysis,land cover change
More info: homepage tracker code repository
Author: Luca Congedo
Upgrade all
Install plugin
Close
Help

- The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);


Plugin installed successfully:
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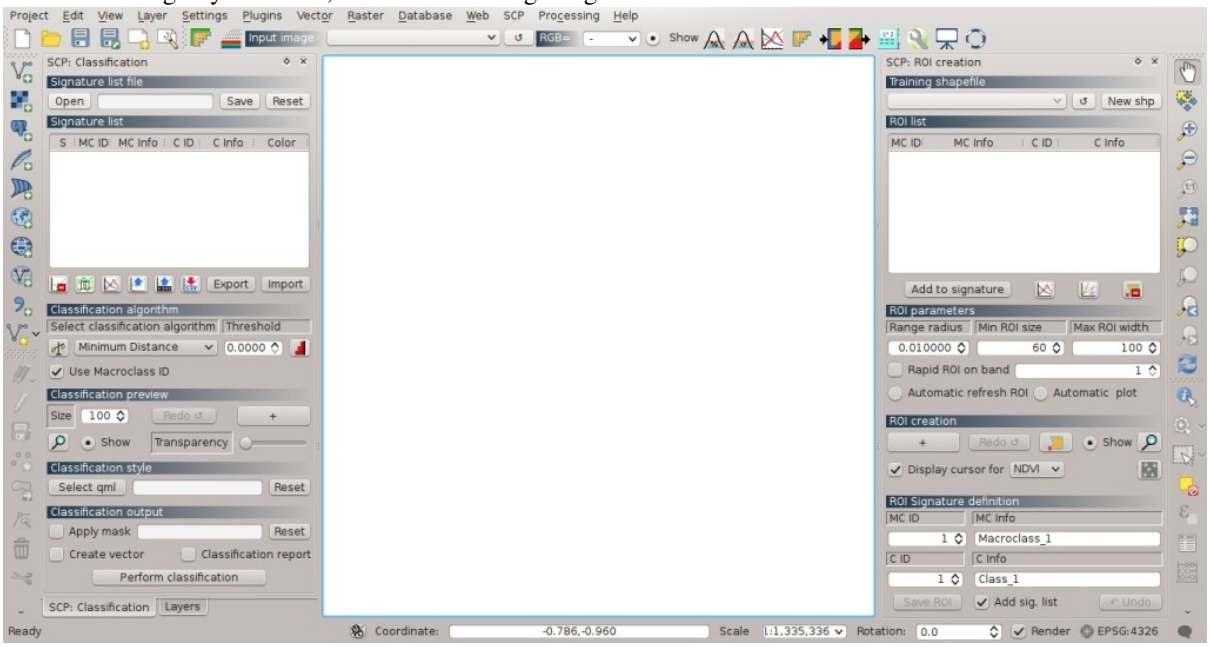
25 rating vote(s), 38811 downloads
Category: Raster
Upgrade all
Uninstall plugin
Reinstall plugin
Close
Help

1.3 Configuration of the plugin

Now, the Semi-Automatic Classification Plugin is installed and two docks and a toolbar should be added to QGIS. Also, a SCP menu is available in the Menu Bar of QGIS. It is possible to move the *Toolbar* (page 87) and the docks according to your needs, as in the following image.



1.4 Known issues

QGIS 32bit installation could include an old version of NumPy as default; in order to use some SCP tools (e.g. *Land cover change* (page 120)), the update of NumPy is required. Please, follow the instructions described in *Error [26] 'The version of Numpy is outdated'. Why?* (page 208).

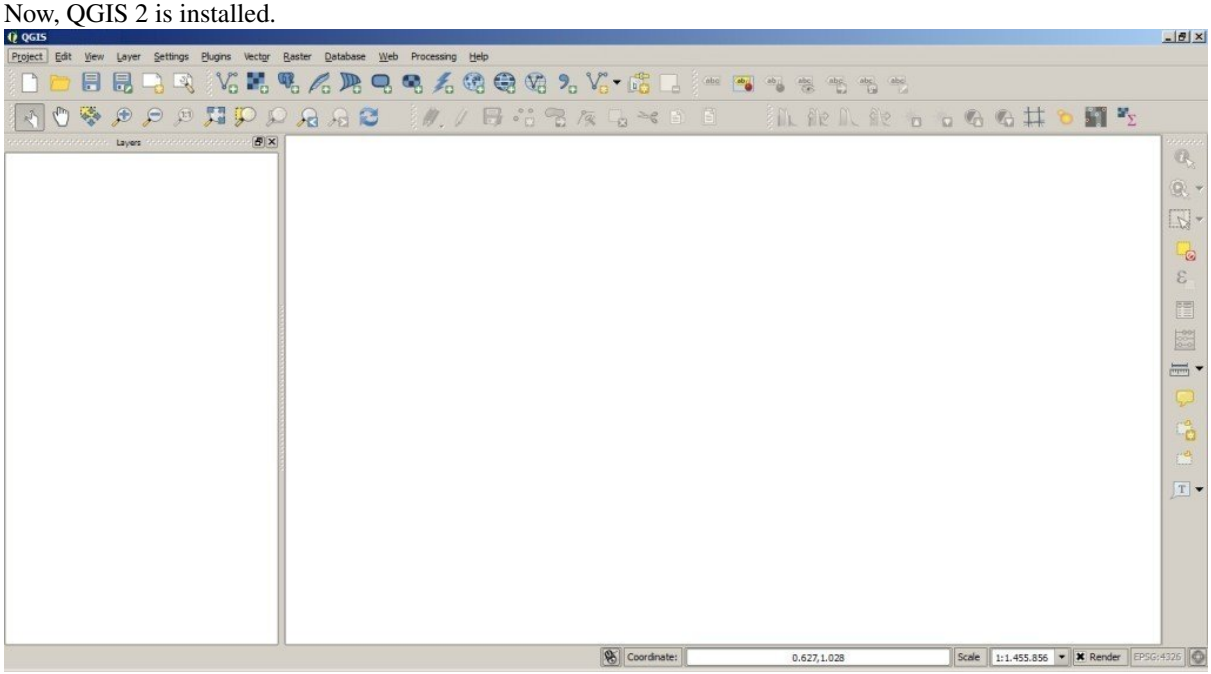
CHAPTER 2

Installation in Windows 64 bit

2.1 QGIS download and installation

- Download the latest QGIS version 64 bit from here (the direct download of QGIS 2.8 from this link);
- Execute the QGIS installer with administrative rights, accepting the default configuration.

Now, QGIS 2 is installed.



2.2 Semi-Automatic Classification Plugin installation

- Run QGIS 2;
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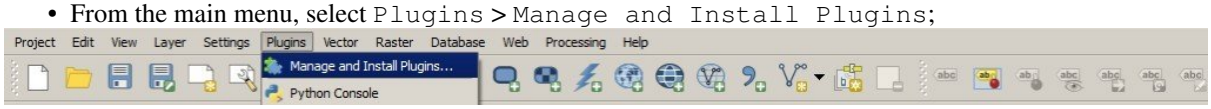
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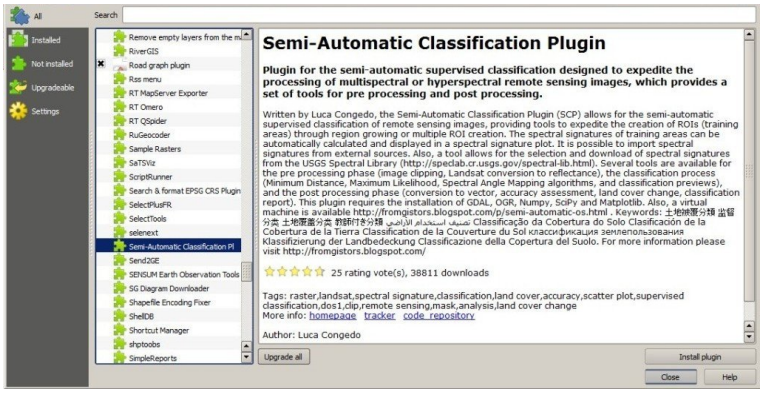
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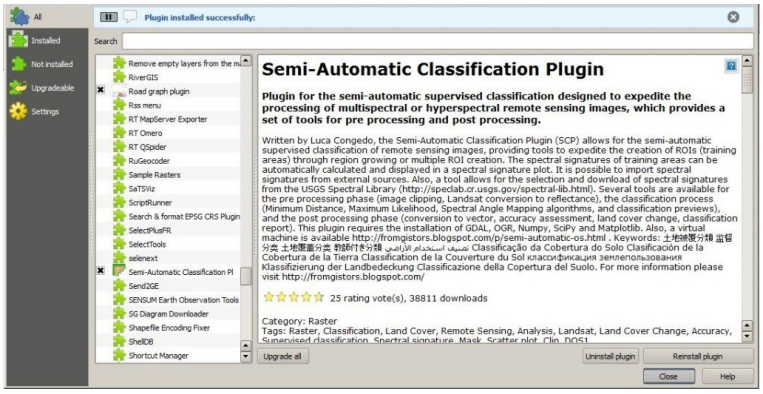
More info: homepage tracker code repository
Author: Luca Congedo
Upgrade all
Install plugin
Close
Help

- The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);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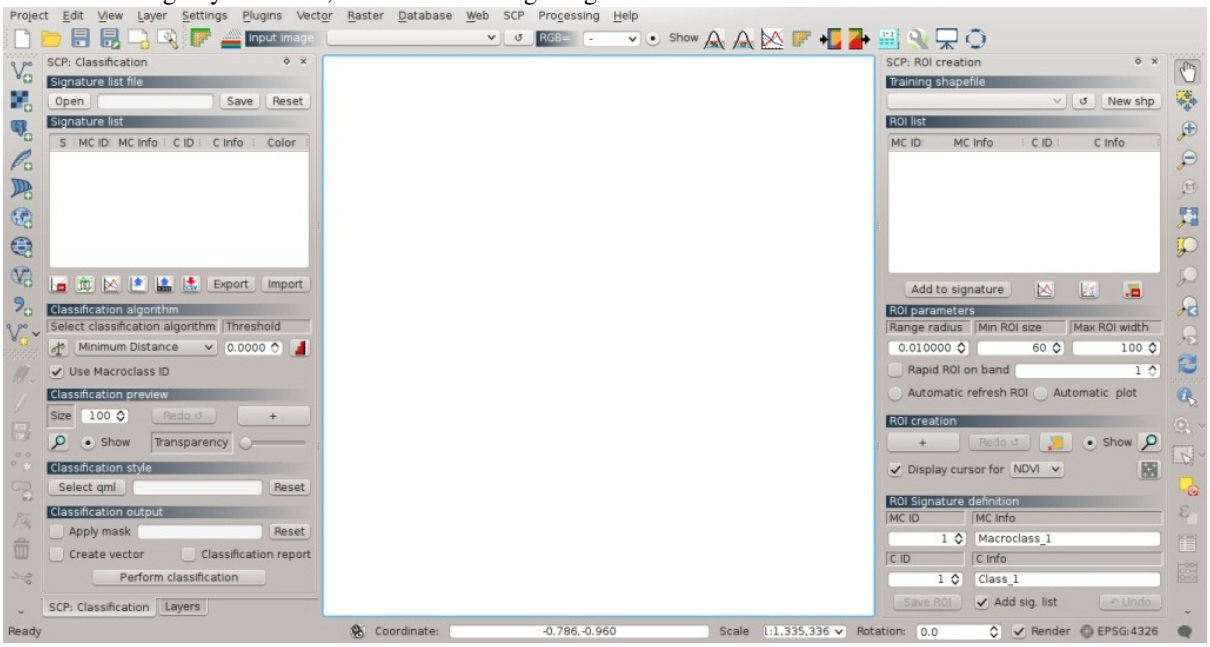
Category: Raster
Tags: Raster, Classification, Land Cover, Remote Sensing, Analysis, Landsat, Land Cover Change, Accuracy,
Upgrade all
Uninstall plugin
Reinstall plugin
Close
Help

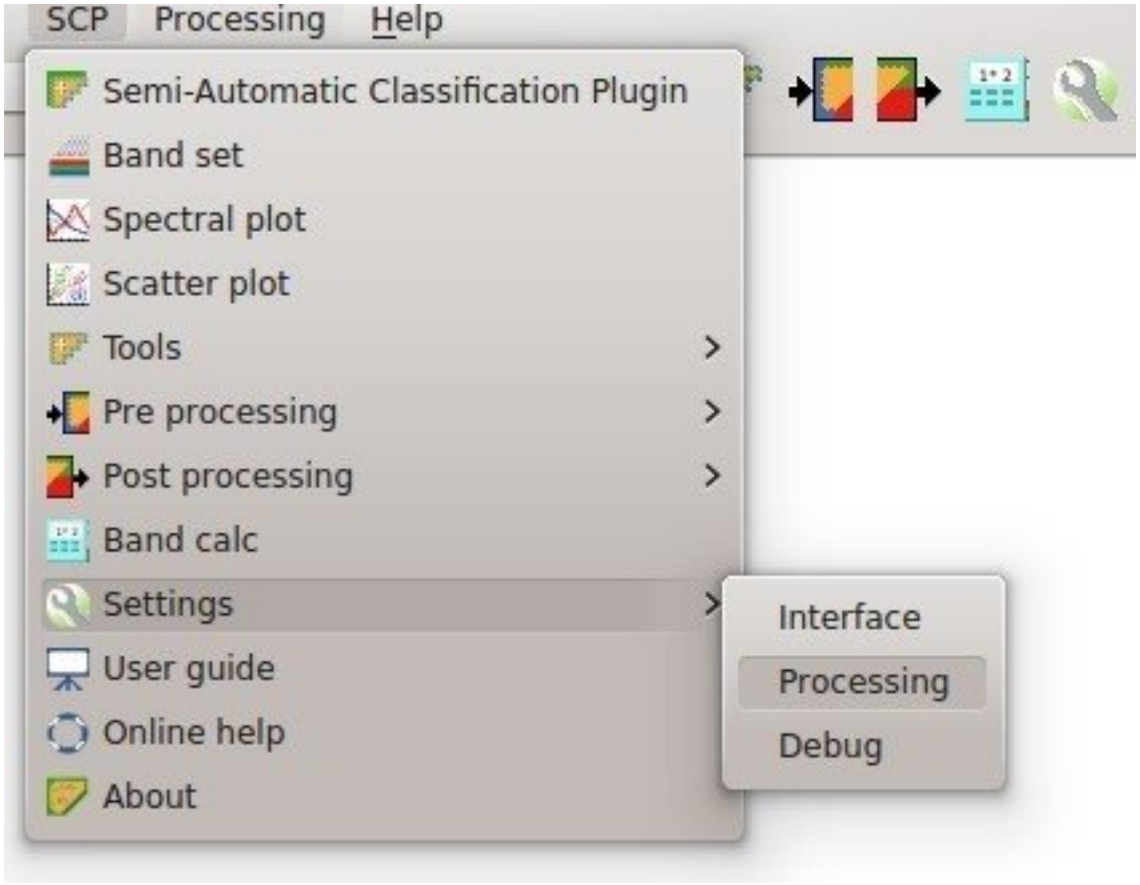
2.3 Configuration of the plugin

Now, the Semi-Automatic Classification Plugin is installed and two docks and a toolbar should be added to QGIS. Also, a SCP menu is available in the Menu Bar of QGIS. It is possible to move the *Toolbar* (page 87) and the docks according to your needs, as in the following image.

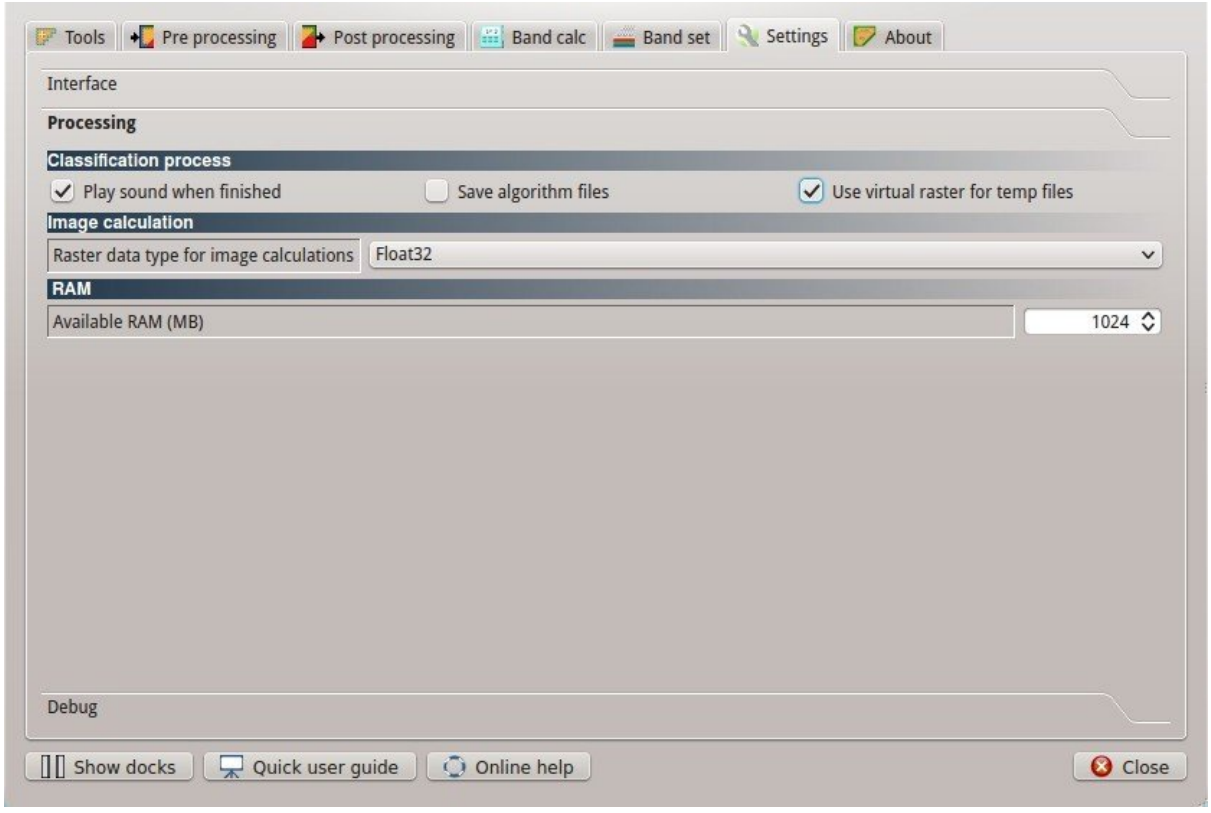


The configuration of available RAM is recommended in order to reduce the processing time. From the *SCP menu*

(page 85) select `Settings > Processing`.



In the *Settings* (page 129), set the `Available RAM (MB)` to a value that should be half of the system RAM. For instance, if your system has 2GB of RAM, set the value to 1024MB.



CHAPTER 3

Installation in Ubuntu Linux

3.1 QGIS download and installation

- Open a terminal and type:

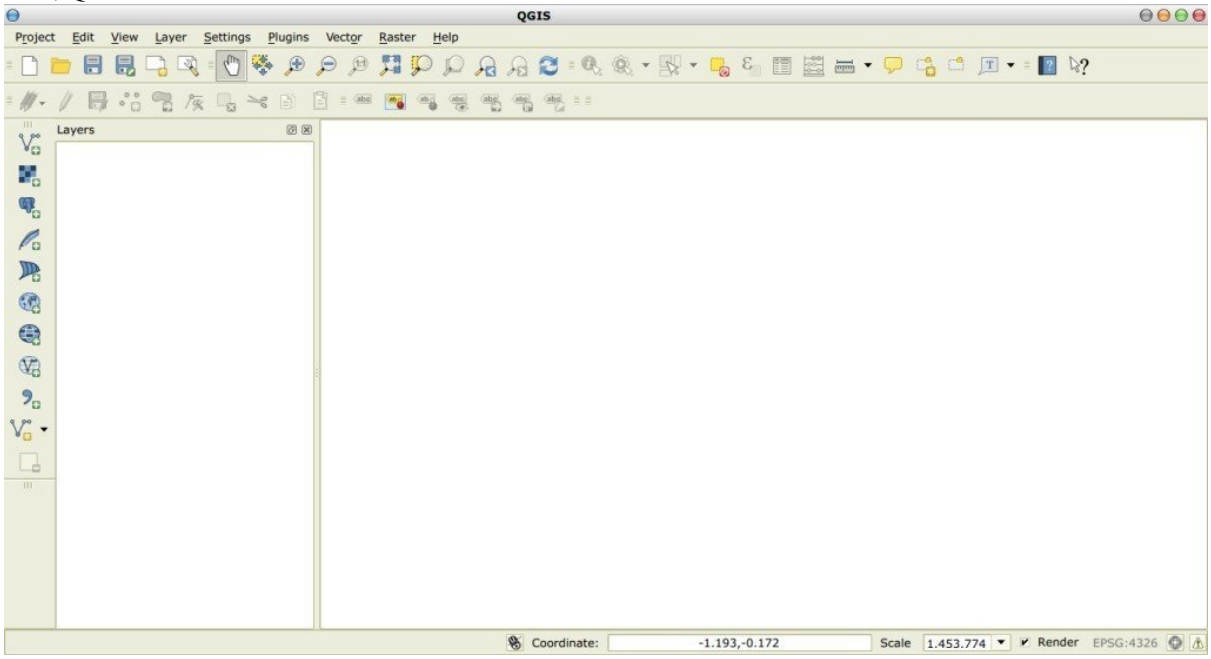
```
sudo apt-get update
```

- Press Enter and type the user password;
- Type in a terminal:

```
sudo apt-get install qgis python-matplotlib python-scipy
```

- Press Enter and wait until the software is downloaded and installed.

Now, QGIS 2 is installed.



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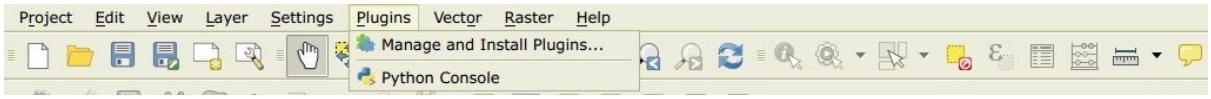
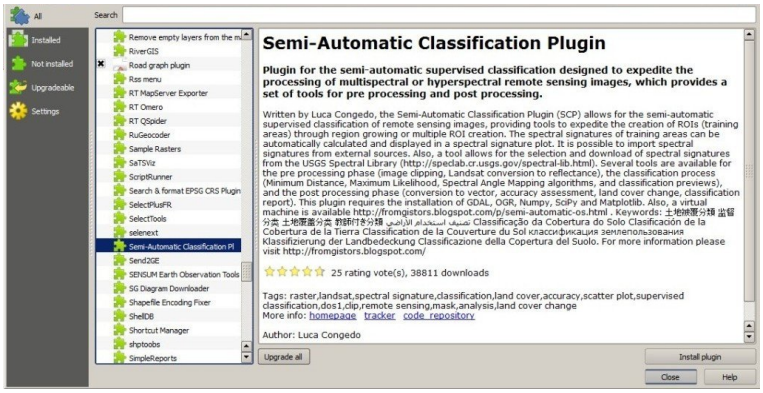
- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;



- From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;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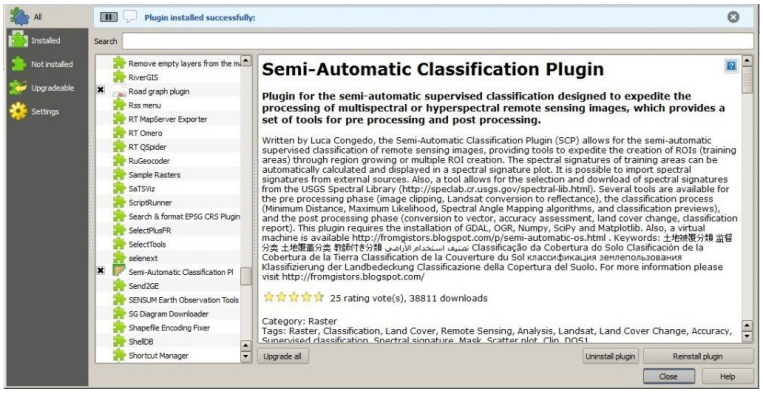
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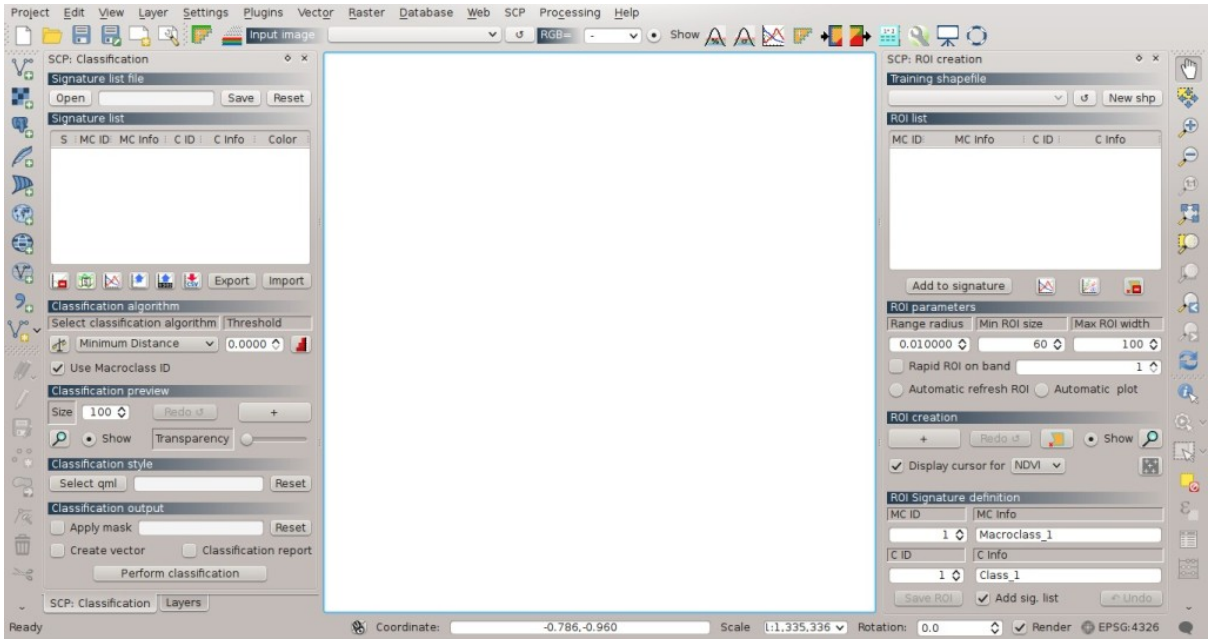
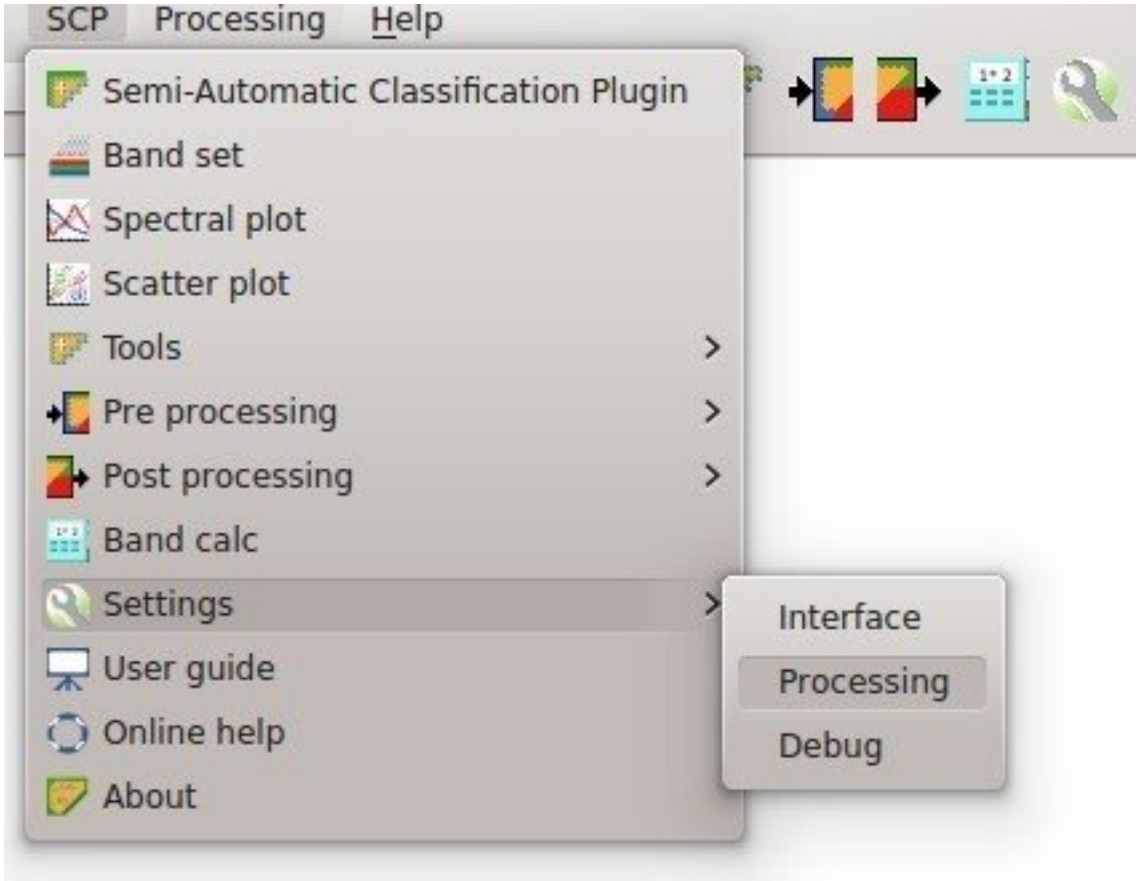
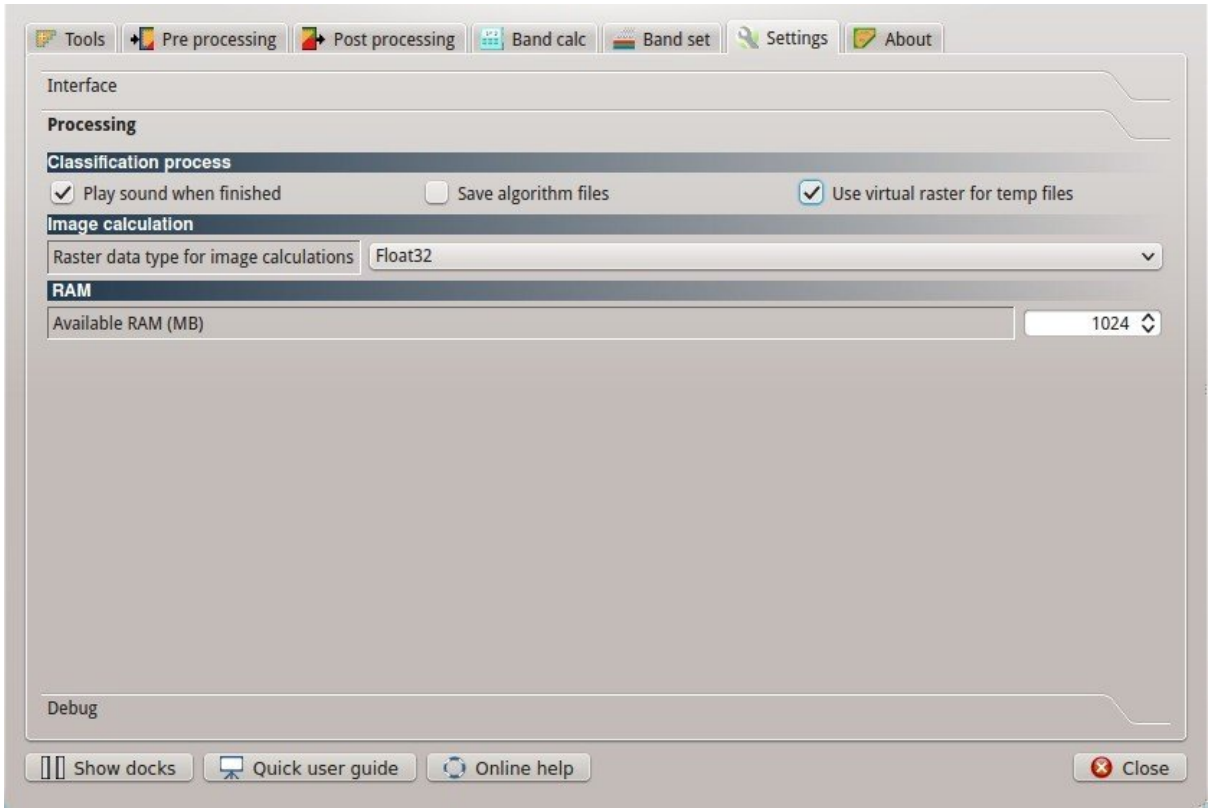


The configuration of available RAM is recommended in order to reduce the processing time. From the *SCP menu* (page 85) select `Settings > Processing`.



In the *Settings* (page 129), set the `Available RAM (MB)` to a value that should be half of the system RAM. For instance, if your system has 2GB of RAM, set the value to 1024MB.


Tools
Pre processing
Post processing
Band calc
Band set
Settings
About
Interface
Processing
Classification process
Play sound when finished
Save algorithm files
Use virtual raster for temp files
Image calculation
Raster data type for image calculations
Float32
RAM
Available RAM (MB)
1024
Debug
Show docks
Quick user guide
Online help
Close

CHAPTER 4

Installation in Debian Linux

4.1 QGIS download and installation

- Open a terminal and type:

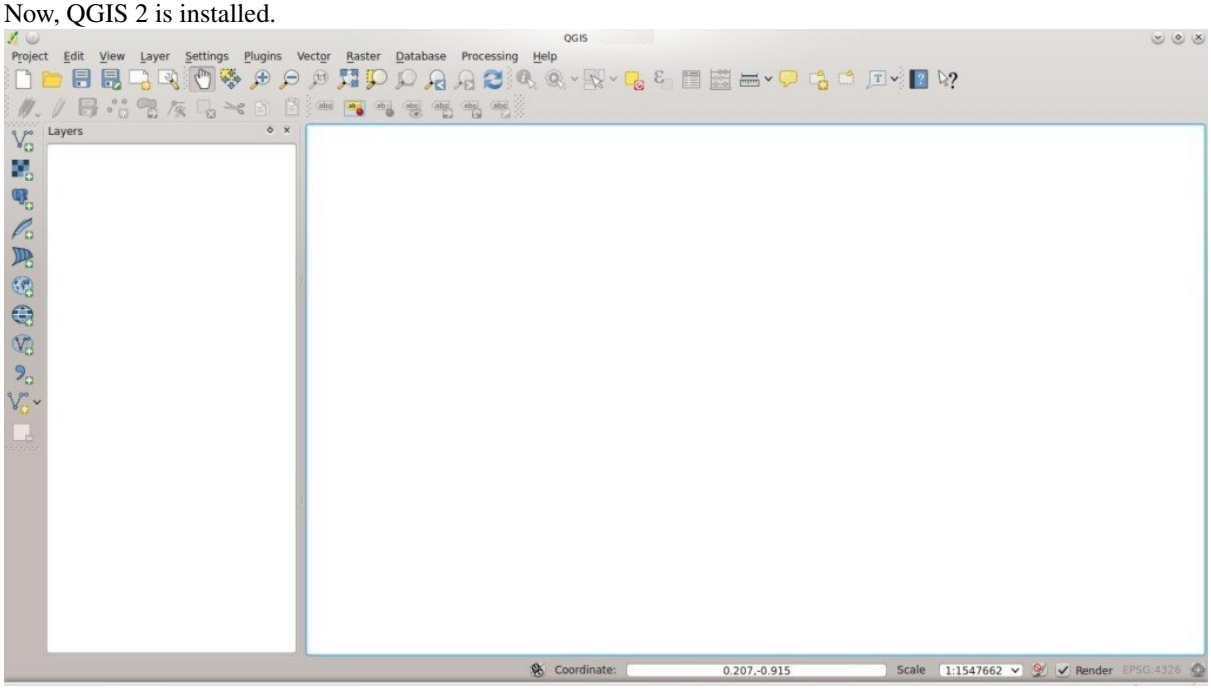
```
sudo apt-get update
```

- Press Enter and type the user password;
- Type in a terminal:

```
sudo apt-get install qgis python-matplotlib python-scipy
```

- Press Enter and wait until the software is downloaded and installed.

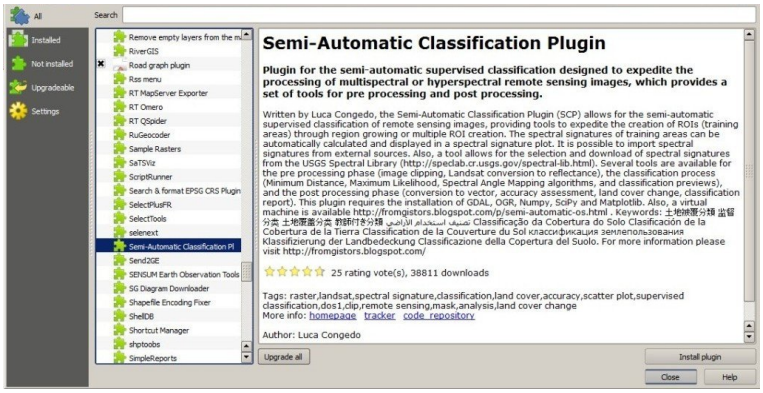
Now, QGIS 2 is installed.



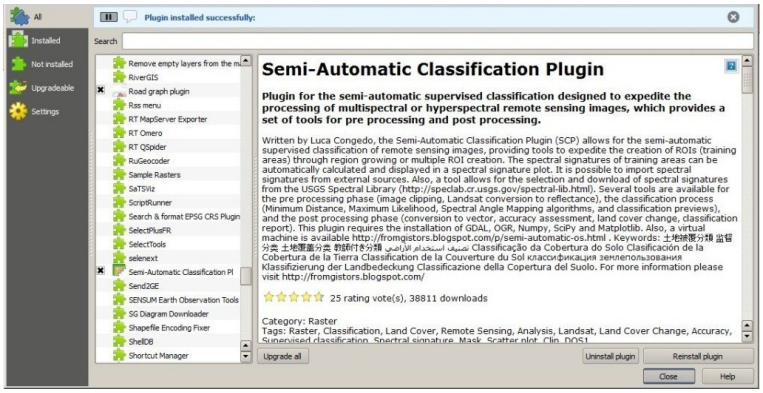
4.2 Semi-Automatic Classification Plugin installation

- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;

- From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;

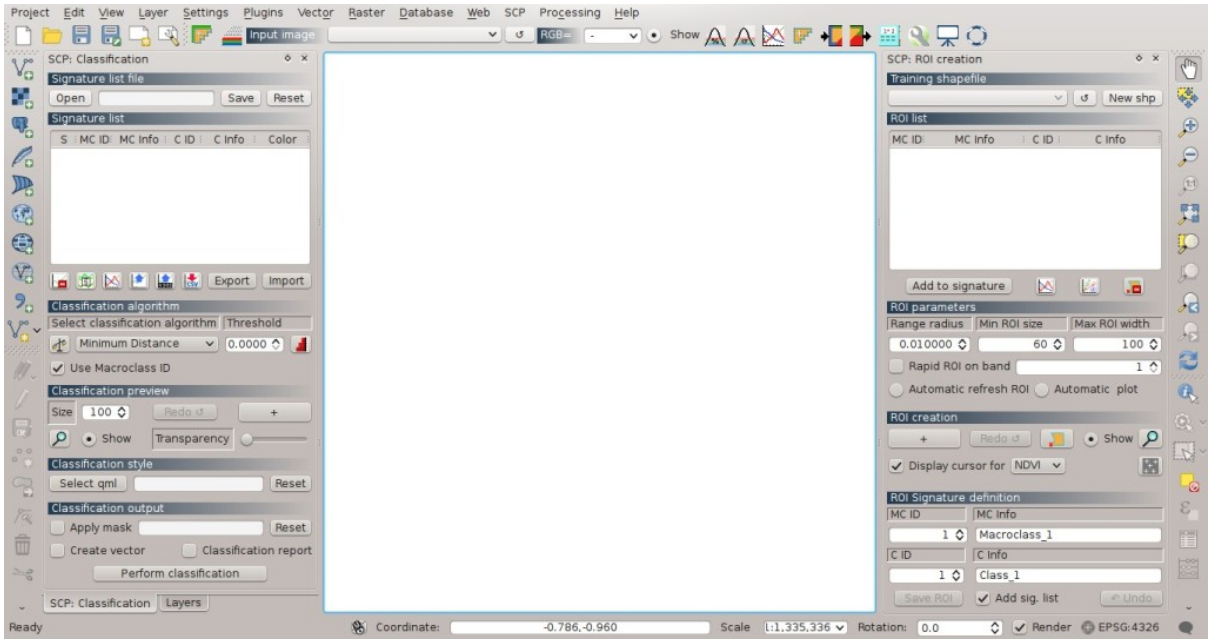

Semi-Automatic Classification Plugin
Plugin for the semi-automatic supervised classification designed to expedite the processing of multispectral or hyperspectral remote sensing images, which provides a set of tools for pre processing and post processing.
Written by Luca Congedo, the Semi-Automatic Classification Plugin (SCP) allows for the semi-automatic supervised classification of remote sensing images, providing tools to expedite the creation of ROIs (training areas) through region growing or multiple ROI creation. The spectral signatures of training areas can be automatically calculated and displayed in a spectral signature plot. It is possible to import spectral signatures from external sources. Also, a tool allows for the selection and download of spectral signatures from the USGS Spectral Library (http://speclab.cr.usgs.gov/spectral-lib.html). Several tools are available for the pre processing phase (image clipping, Landsat conversion to reflectance), the classification process (Minimum Distance, Maximum Likelihood, Spectral Angle Mapping algorithms, and classification previews), and the post processing phase (conversion to vector, accuracy assessment, land cover change, classification report). This plugin requires the installation of GDAL, OGR, Numpy, SciPy and Matplotlib. Also, a virtual machine is available http://fromgistors.blogspot.com/p/semi-automatic-os.html . Keywords: 土地被覆分類 监督分类 土地覆盖分类 教師付き分類 تصنيف باستخدام الإشراف Classificação da Cobertura do Solo Clasificación de la Cobertura de la Tierra Classification de la Couverture du Sol классификация землепользования Klassifizierung der Landbedeckung Classificazione della Copertura del Suolo. For more information please visit http://fromgistors.blogspot.com/
25 rating vote(s), 38811 downloads
Tags: raster,landsat,spectral signature,classification,land cover,accuracy,scatter plot,supervised classification,dos1,dip,remote sensing,mask,analysis,land cover change
More info: homepage tracker code repository
Author: Luca Congedo
Upgrade all
Install plugin
Close
Help

- The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);

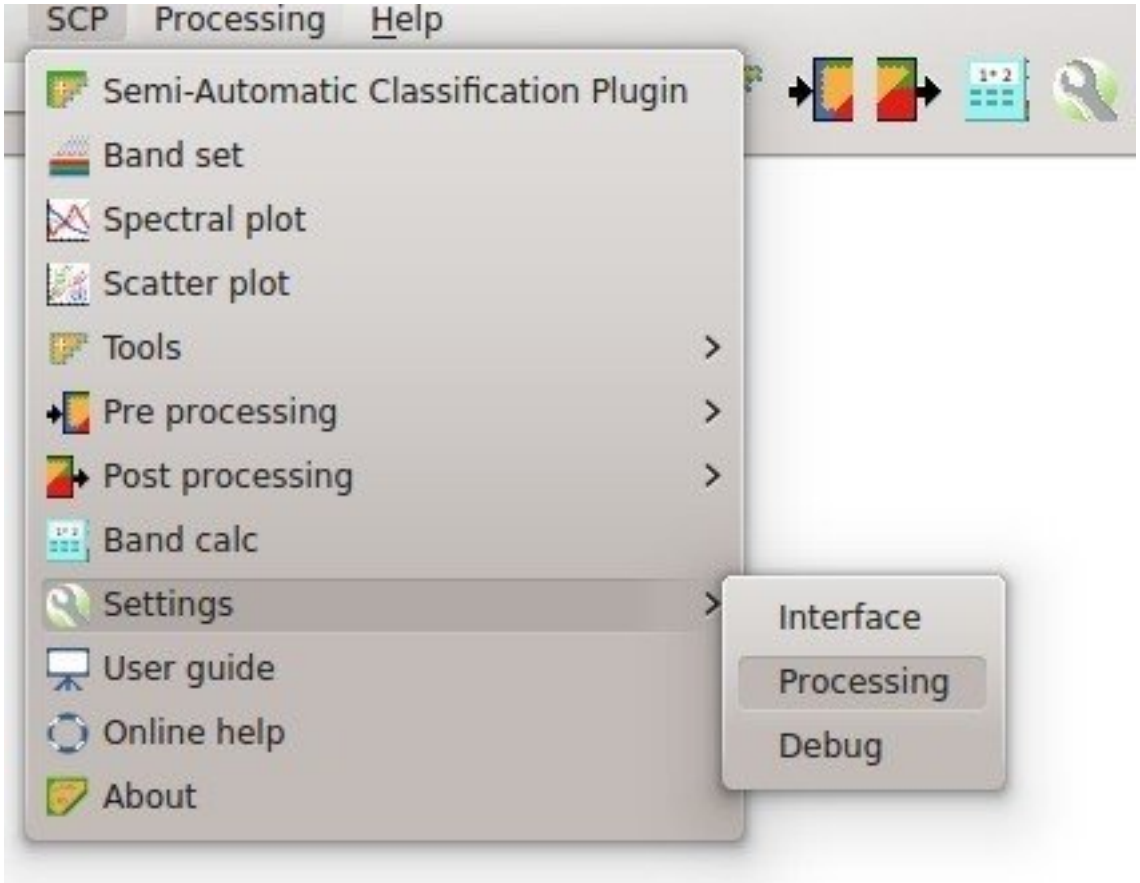

Plugin installed successfully:
Semi-Automatic Classification Plugin
Plugin for the semi-automatic supervised classification designed to expedite the processing of multispectral or hyperspectral remote sensing images, which provides a set of tools for pre processing and post processing.
25 rating vote(s), 38811 downloads
Uninstall plugin
Reinstall plugin
Close
Help

4.3 Configuration of the plugin

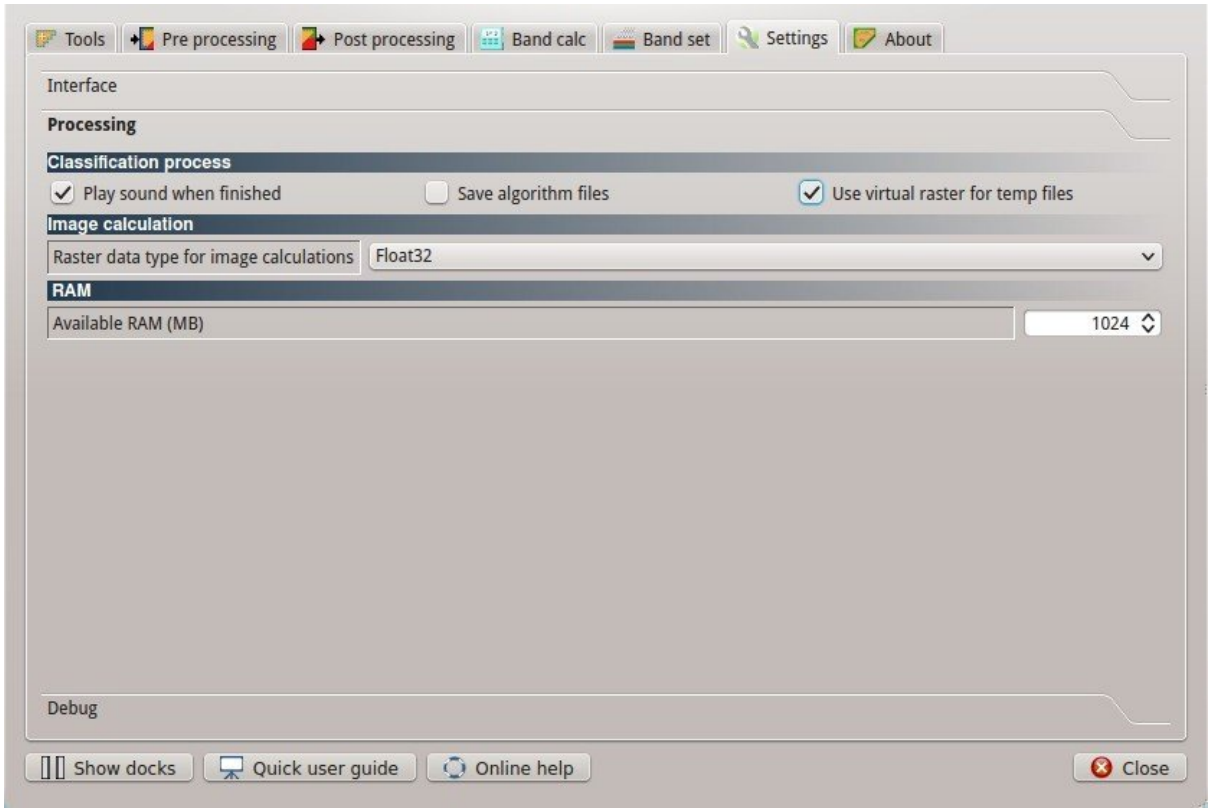
Now, the Semi-Automatic Classification Plugin is installed and two docks and a toolbar should be added to QGIS. Also, a SCP menu is available in the Menu Bar of QGIS. It is possible to move the *Toolbar* (page 87) and the docks according to your needs, as in the following image.



The configuration of available RAM is recommended in order to reduce the processing time. From the *SCP menu* (page 85) select `Settings > Processing`.



In the *Settings* (page 129), set the `Available RAM (MB)` to a value that should be half of the system RAM. For instance, if your system has 2GB of RAM, set the value to 1024MB.


Tools
Pre processing
Post processing
Band calc
Band set
Settings
About
Interface
Processing
Classification process
Play sound when finished
Save algorithm files
Use virtual raster for temp files
Image calculation
Raster data type for image calculations
Float32
RAM
Available RAM (MB)
1024
Debug
Show docks
Quick user guide
Online help
Close

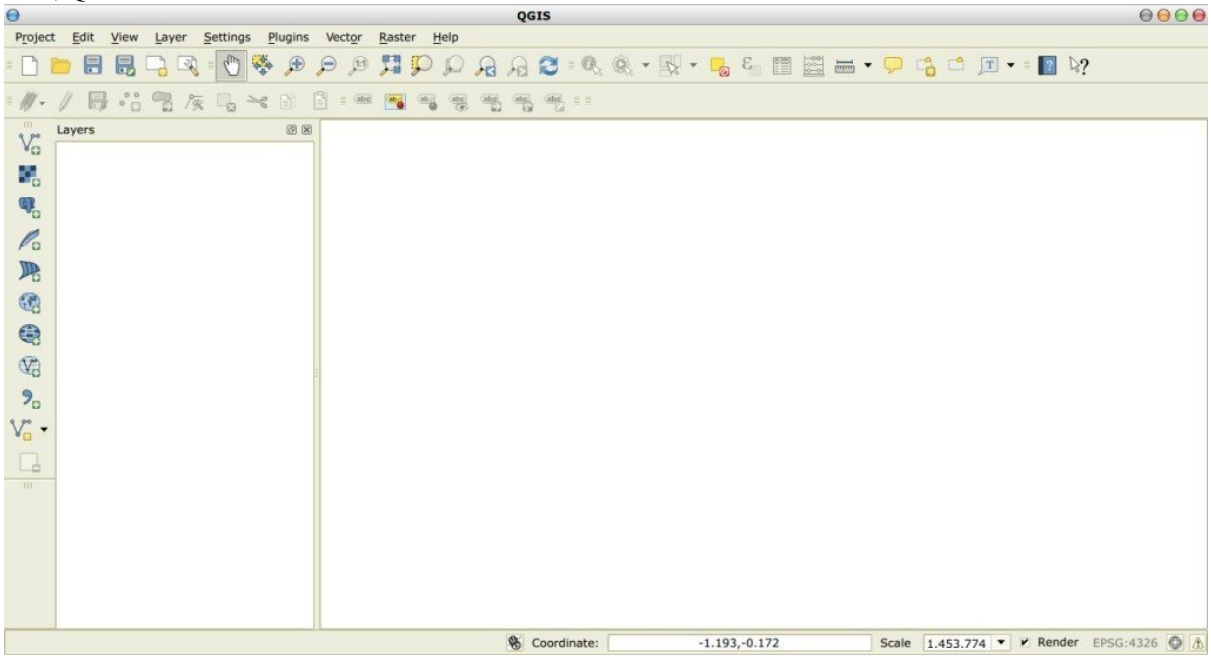
CHAPTER 5

Installation in Mac OS

5.1 QGIS download and installation

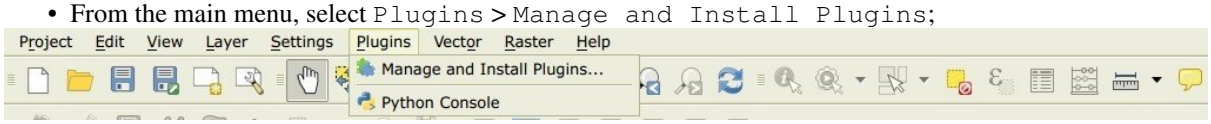
- Download and install the latest version of QGIS and GDAL from here .
- In addition, download and install the python modules Numpy, Scipy, and Matplotlib from this link .

Now, QGIS 2 is installed.

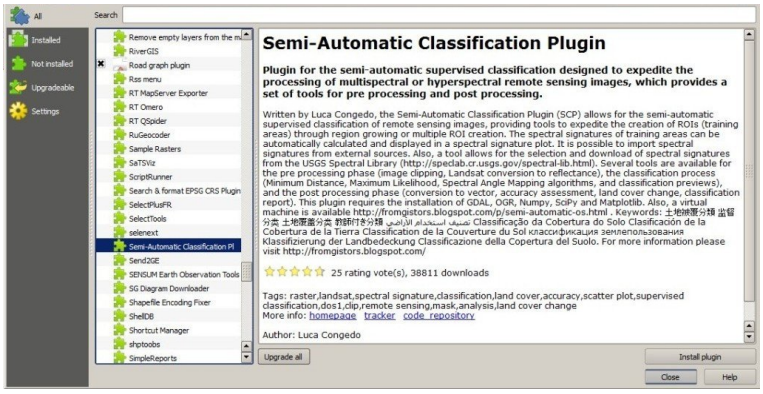


5.2 Semi-Automatic Classification Plugin installation

- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;



- From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;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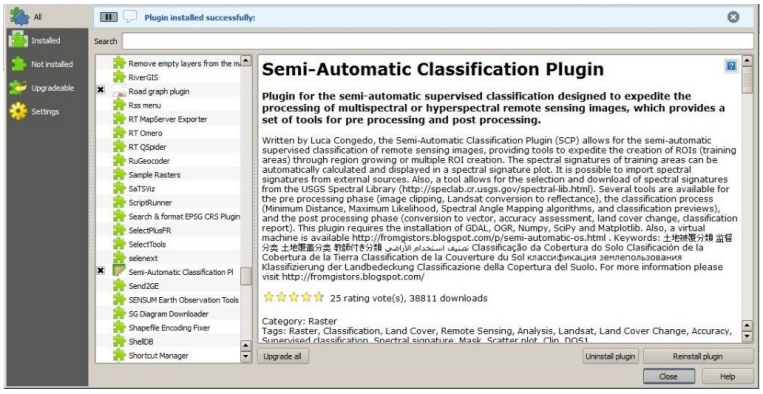
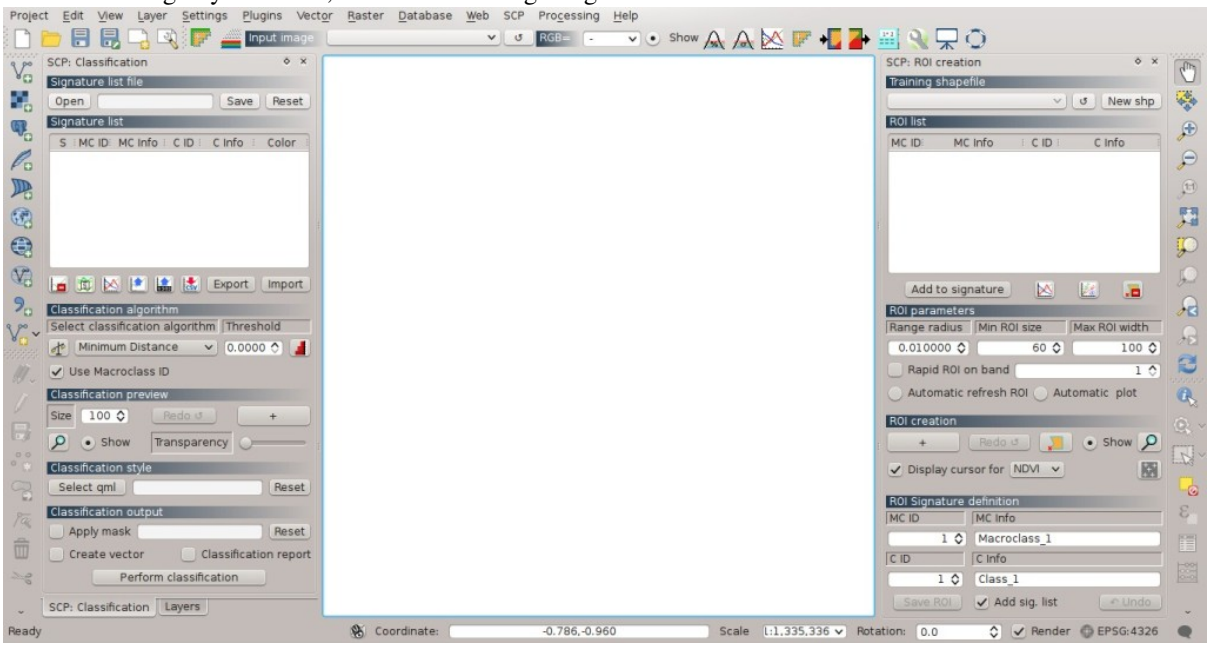
25 rating vote(s), 38811 downloads
Tags: raster,landsat,spectral signature,classification,land cover,accuracy,scatter plot,supervised classification,dos1,clip,remote sensing,mask,analysis,land cover change
More info: homepage tracker code repository
Author: Luca Congedo
Upgrade all
Install plugin
Close
Help

- The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);


Plugin installed successfully:
Semi-Automatic Classification Plugin
Plugin for the semi-automatic supervised classification designed to expedite the processing of multispectral or hyperspectral remote sensing images, which provides a set of tools for pre processing and post processing.
25 rating vote(s), 38811 downloads
Category: Raster
Tags: Raster, Classification, Land Cover, Remote Sensing, Analysis, Landsat, Land Cover Change, Accuracy,
Upgrade all
Uninstall plugin
Reinstall plugin
Close
Help

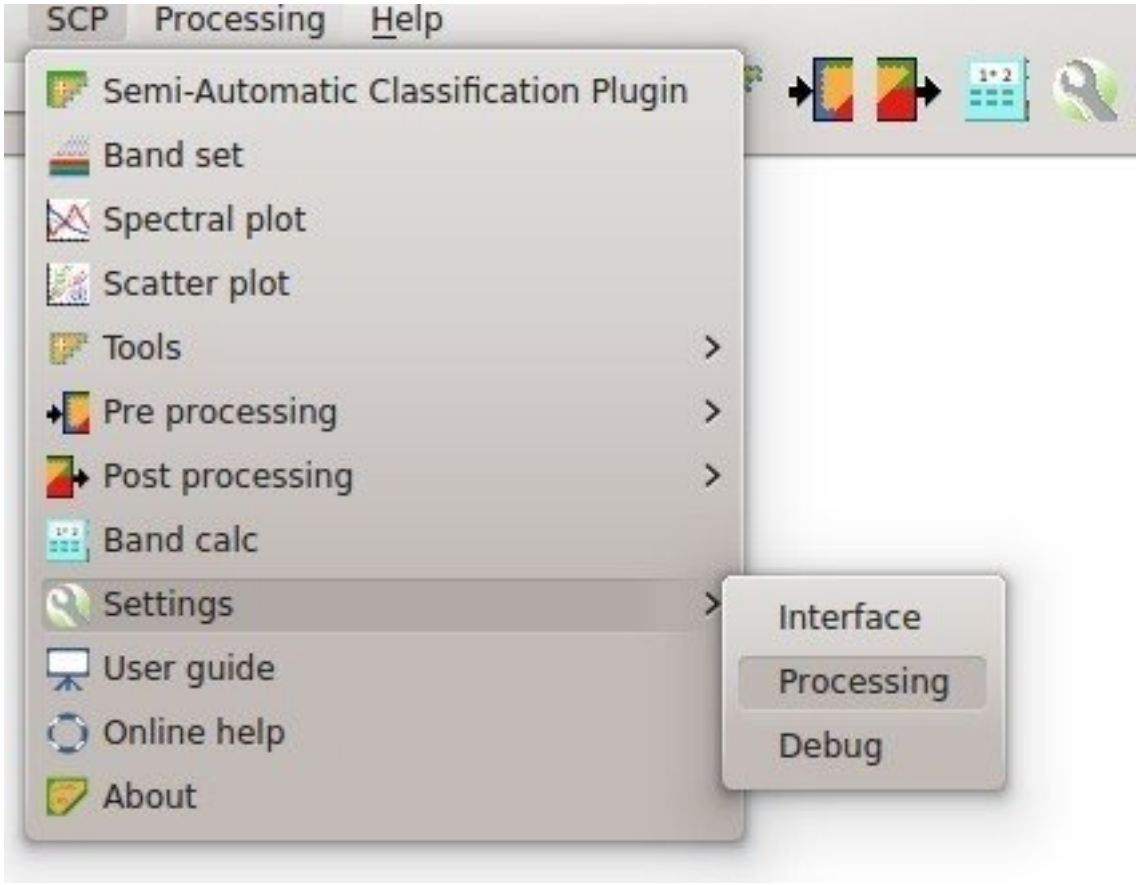
5.3 Configuration of the plugin

Now, the Semi-Automatic Classification Plugin is installed and two docks and a toolbar should be added to QGIS. Also, a SCP menu is available in the Menu Bar of QGIS. It is possible to move the *Toolbar* (page 87) and the docks according to your needs, as in the following image.

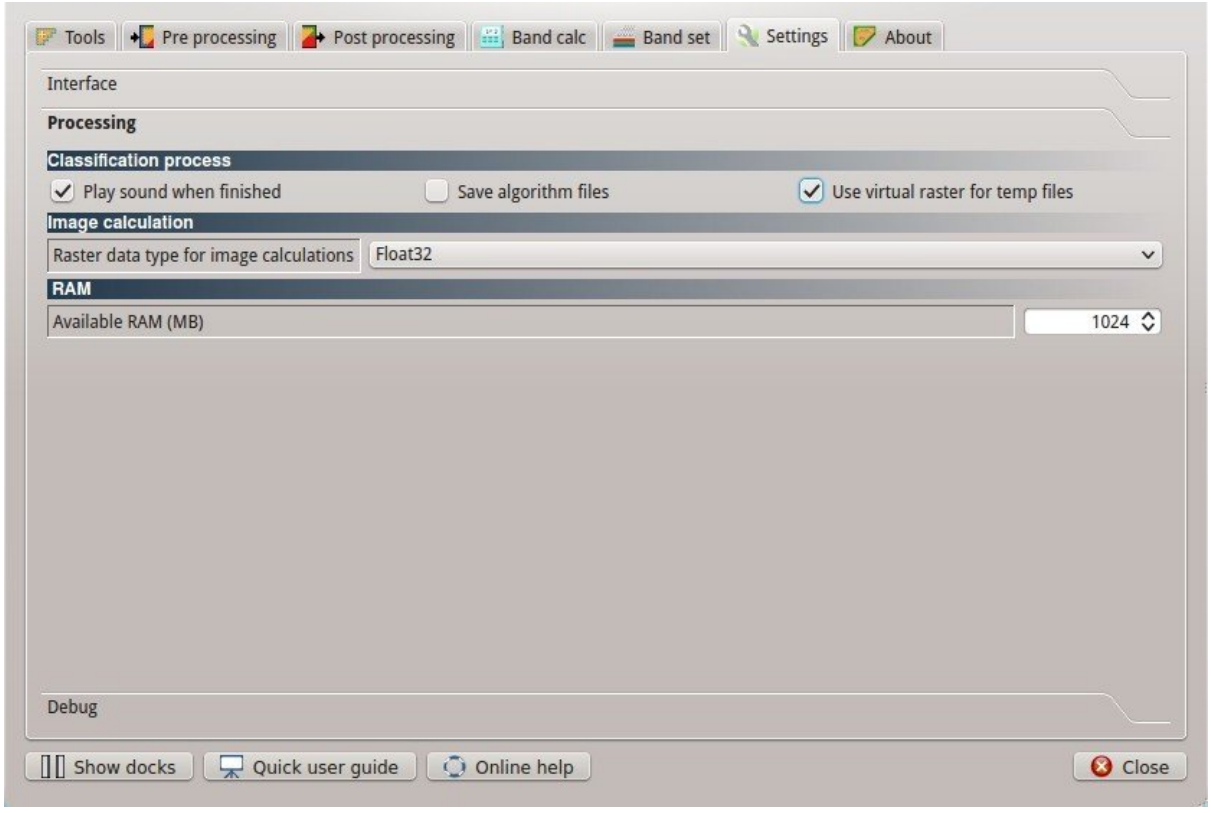


The configuration of available RAM is recommended in order to reduce the processing time. From the *SCP menu*

(page 85) select `Settings > Processing`.



In the *Settings* (page 129), set the `Available RAM (MB)` to a value that should be half of the system RAM. For instance, if your system has 2GB of RAM, set the value to 1024MB.



Part II

Brief Introduction to Remote Sensing

- *Basic Definitions* (page 31)
  - *GIS definition* (page 31)
  - *Remote Sensing definition* (page 31)
  - *Sensors* (page 33)
  - *Radiance and Reflectance* (page 33)
  - *Spectral Signature* (page 33)
  - *Landsat Satellite* (page 34)
  - *Sentinel-2 Satellite* (page 34)
  - *Color Composite* (page 35)
  - *Pan-sharpening* (page 35)
- *Supervised Classification Definitions* (page 39)
  - *Land Cover* (page 39)
  - *Supervised Classification* (page 39)
  - *Training Areas* (page 39)
  - *Classes and Macroclasses* (page 39)
  - *Classification Algorithms* (page 40)
  - *Spectral Distance* (page 42)
  - *Classification Result* (page 44)
  - *Accuracy Assessment* (page 44)
- *Landsat image conversion to reflectance and DOS1 atmospheric correction* (page 47)
  - *Radiance at the Sensor's Aperture* (page 47)
  - *Top Of Atmosphere (TOA) Reflectance* (page 47)
  - *Surface Reflectance* (page 48)
  - *DOS1 Correction* (page 48)
- *Conversion to At-Satellite Brightness Temperature* (page 51)

CHAPTER 6

Basic Definitions

This chapter provides basic definitions about GIS and remote sensing.

6.1 GIS definition

There are several definitions of **GIS** (Geographic Information Systems), which is not simply a program. In general, GIS are systems that allow for the use of geographic information (data have spatial coordinates). In particular, GIS allow for the view, query, calculation and analysis of spatial data, which are mainly distinguished in raster or vector data structures. Vector is made of objects that can be points, lines or polygons, and each object can have one ore more attribute values; a raster is a grid (or image) where each cell has an attribute value (Fisher and Unwin, 2005). Several GIS applications use raster images that are derived from remote sensing.

6.2 Remote Sensing definition

A general definition of **Remote Sensing** is "the science and technology by which the characteristics of objects of interest can be identified, measured or analyzed the characteristics without direct contact" (JARS, 1993).

Usually, remote sensing is the measurement of the energy that is emanated from the Earth's surface. If the source of the measured energy is the sun, then it is called **passive remote sensing**, and the result of this measurement can be a digital image (Richards and Jia, 2006). If the measured energy is not emitted by the Sun but from the sensor platform then it is defined as **active remote sensing**, such as radar sensors which work in the microwave range (Richards and Jia, 2006).

The **electromagnetic spectrum** is "the system that classifies, according to wavelength, all energy (from short cosmic to long radio) that moves, harmonically, at the constant velocity of light" (NASA, 2013). Passive sensors measure energy from the optical regions of the electromagnetic spectrum: visible, near infrared (i.e. IR), short-wave IR, and thermal IR (see Figure *Electromagnetic-Spectrum* (page 32)).

The interaction between solar energy and materials depends on the wavelength; solar energy goes from the Sun to the Earth and then to the sensor. Along this path, **solar energy** is (NASA, 2013):

- **Transmitted** - The energy passes through with a change in velocity as determined by the index of refraction for the two media in question.
- **Absorbed** - The energy is given up to the object through electron or molecular reactions.
- **Reflected** - The energy is returned unchanged with the angle of incidence equal to the angle of reflection. Reflectance is the ratio of reflected energy to that incident on a body. The wavelength reflected (not absorbed) determines the color of an object.
- **Scattered** - The direction of energy propagation is randomly changed. Rayleigh and Mie scatter are the two most important types of scatter in the atmosphere.
- **Emitted** - Actually, the energy is first absorbed, then re-emitted, usually at longer wavelengths. The object heats up.

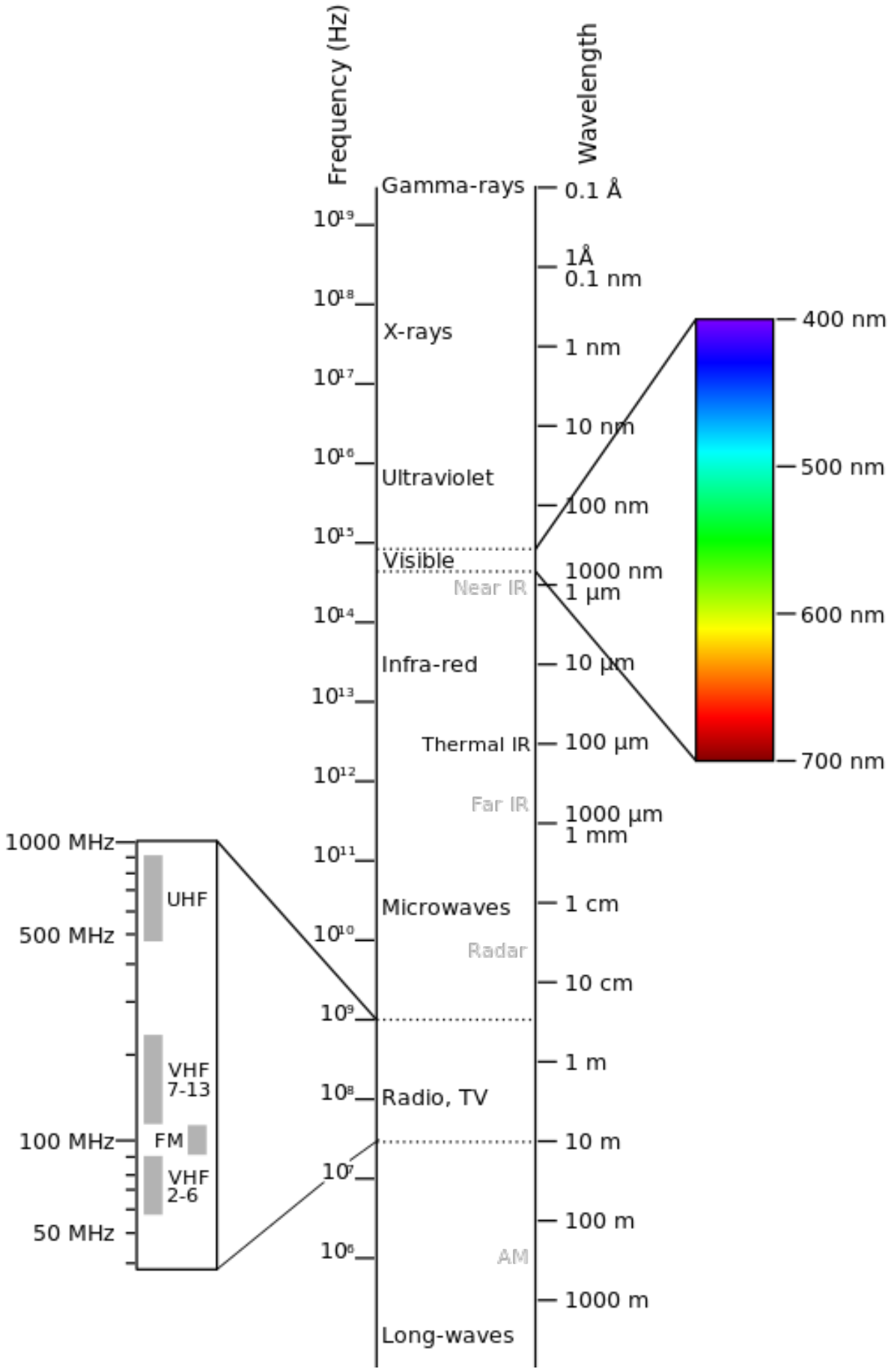


Fig. 6.1: *Electromagnetic-Spectrum*
by Victor Blacus (SVG version of File:Electromagnetic-Spectrum.png)
[CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)]
via Wikimedia Commons
http://commons.wikimedia.org/wiki/File%3AElectromagnetic-Spectrum.svg

6.3 Sensors

Sensors can be on board of airplanes or on board of satellites, measuring the electromagnetic radiation at specific ranges (usually called bands). As a result, the measures are quantized and converted into a digital image, where each picture elements (i.e. pixel) has a discrete value in units of Digital Number (DN) (NASA, 2013). The resulting images have different characteristics (resolutions) depending on the sensor. There are several kinds of **resolutions**:

- **Spatial resolution**, usually measured in pixel size, "is the resolving power of an instrument needed for the discrimination of features and is based on detector size, focal length, and sensor altitude" (NASA, 2013); spatial resolution is also referred to as geometric resolution or IFOV;
- **Spectral resolution**, is the number and location in the electromagnetic spectrum (defined by two wavelengths) of the spectral bands (NASA, 2013) in multispectral sensors, for each band corresponds an image;
- **Radiometric resolution**, usually measured in bits (binary digits), is the range of available brightness values, which in the image correspond to the maximum range of DNs; for example an image with 8 bit resolution has 256 levels of brightness (Richards and Jia, 2006);
- For satellites sensors, there is also the **temporal resolution**, which is the time required for revisiting the same area of the Earth (NASA, 2013).

6.4 Radiance and Reflectance

Sensors measure the **radiance**, which corresponds to the brightness in a given direction toward the sensor; it useful to define also the **reflectance** as the ratio of reflected versus total power energy.

6.5 Spectral Signature

The **spectral signature** is the reflectance as a function of wavelength (see Figure *Spectral Reflectance Curves of Four Different Targets* (page 33)); each material has a unique signature, therefore it can be used for material classification (NASA, 2013).

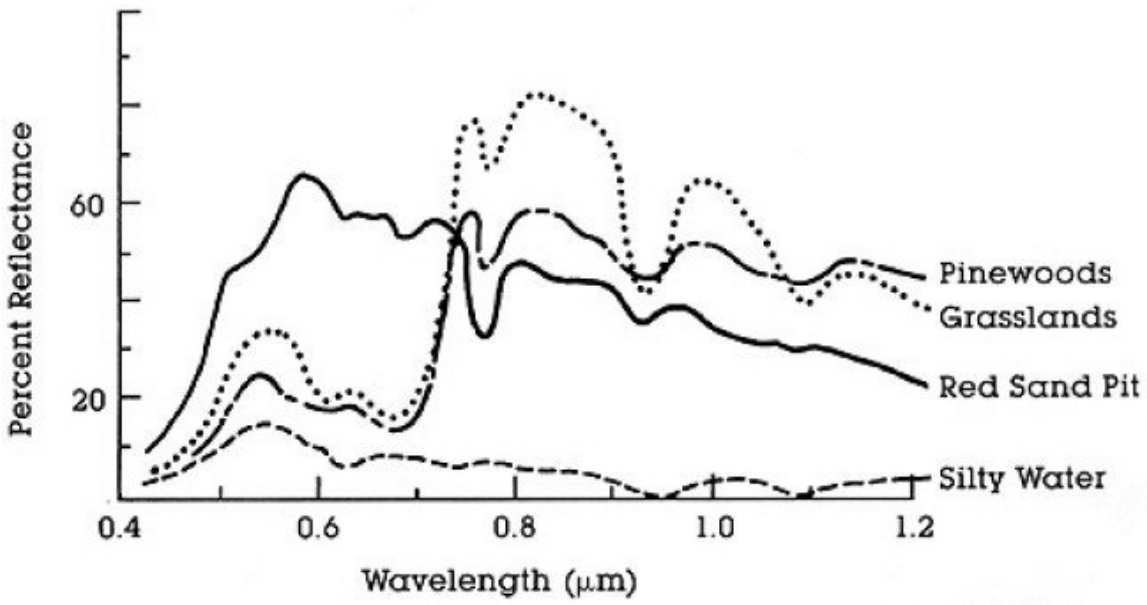


Fig. 6.2: *Spectral Reflectance Curves of Four Different Targets*
(from NASA, 2013)

6.6 Landsat Satellite

Landsat is a set of multispectral satellites developed by the NASA (National Aeronautics and Space Administration of USA), since the early 1970's.

Landsat images are very used for environmental research. The resolutions of Landsat 4 and Landsat 5 sensors are reported in the following table (from http://landsat.usgs.gov/band_designations_landsat_satellites.php); also, Landsat temporal resolution is 16 days (NASA, 2013).

Landsat 4, Landsat 5 Bands	Wavelength [micrometers]	Resolution [meters]
Band 1 - Blue	0.45 - 0.52	30
Band 2 - Green	0.52 - 0.60	30
Band 3 - Red	0.63 - 0.69	30
Band 4 - Near Infrared (NIR)	0.76 - 0.90	30
Band 5 - SWIR	1.55 - 1.75	30
Band 6 - Thermal Infrared	10.40 - 12.50	120 (resampled to 30)
Band 7 - SWIR	2.08 - 2.35	30

The resolutions of Landsat 7 sensor are reported in the following table (from http://landsat.usgs.gov/band_designations_landsat_satellites.php); also, Landsat temporal resolution is 16 days (NASA, 2013).

Landsat 7 Bands	Wavelength [micrometers]	Resolution [meters]
Band 1 - Blue	0.45 - 0.52	30
Band 2 - Green	0.52 - 0.60	30
Band 3 - Red	0.63 - 0.69	30
Band 4 - Near Infrared (NIR)	0.77 - 0.90	30
Band 5 - SWIR	1.57 - 1.75	30
Band 6 - Thermal Infrared	10.40 - 12.50	60 (resampled to 30)
Band 7 - SWIR	2.09 - 2.35	30
Band 8 - Panchromatic	0.52 - 0.90	15

The resolutions of Landsat 8 sensor are reported in the following table (from http://landsat.usgs.gov/band_designations_landsat_satellites.php); also, Landsat temporal resolution is 16 days (NASA, 2013).

Landsat 8 Bands	Wavelength [micrometers]	Resolution [meters]
Band 1 - Coastal aerosol	0.43 - 0.45	30
Band 2 - Blue	0.45 - 0.51	30
Band 3 - Green	0.53 - 0.59	30
Band 4 - Red	0.64 - 0.67	30
Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
Band 6 - SWIR 1	1.57 - 1.65	30
Band 7 - SWIR 2	2.11 - 2.29	30
Band 8 - Panchromatic	0.50 - 0.68	15
Band 9 - Cirrus	1.36 - 1.38	30
Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 (resampled to 30)
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 (resampled to 30)

A vast archive of images is freely available from the U.S. Geological Survey . For more information about how to freely download Landsat images read this .

6.7 Sentinel-2 Satellite

Sentinel-2 is a multispectral satellite developed by the European Space Agency (ESA) in the frame of Copernicus land monitoring services. Sentinel-2 acquires 13 spectral bands with the spatial resolution of 10m, 20m and 60m depending on the band, as illustrated in the following table (ESA, 2015).

Sentinel-2 Bands	Central Wavelength [micrometers]	Resolution [meters]
Band 1 - Coastal aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - Vegetation Red Edge	0.865	20
Band 9 - Water vapour	0.945	60
Band 10 - SWIR - Cirrus	1.375	60
Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

Sentinel-2 images are freely available from the ESA website https://scihub.esa.int/dhus/ .

6.8 Color Composite

Often, a combination is created of three individual monochrome images, in which each is assigned a given color; this is defined **color composite** and is useful for photo interpretation (NASA, 2013). Color composites are usually expressed as:

"R G B = Br Bg Bb"

where:

- R stands for Red;
- G stands for Green;
- B stands for Blue;
- Br is the band number associated to the Red color;
- Bg is the band number associated to the Green color;
- Bb is the band number associated to the Blue color.

The following Figure *Color composite of a Landsat 8 image* (page 36) shows a color composite "R G B = 4 3 2" of a Landsat 8 image (for Landsat 7 the same color composite is R G B = 3 2 1) and a color composite "R G B = 5 4 3" (for Landsat 7 the same color composite is R G B = 4 3 2). The composite "R G B = 5 4 3" is useful for the interpretation of the image because vegetation pixels appear red (healthy vegetation reflects a large part of the incident light in the near-infrared wavelength, resulting in higher reflectance values for band 5, thus higher values for the associated color red).

6.9 Pan-sharpening

Pan-sharpening is the combination of the spectral information of multispectral bands (MS), which have lower spatial resolution (for Landsat bands, spatial resolution is 30m), with the spatial resolution of a panchromatic band (PAN), which for Landsat 7 and 8 it is 15m. The result is a multispectral image with the spatial resolution of the panchromatic band (e.g. 15m). In SCP, a Brovey Transform is applied, where the pan-sharpened values of each multispectral band are calculated as (Johnson, Tateishi and Hoan, 2012):

$$MSpan = MS * PAN/I$$

where I is Intensity, which is a function of multispectral bands.

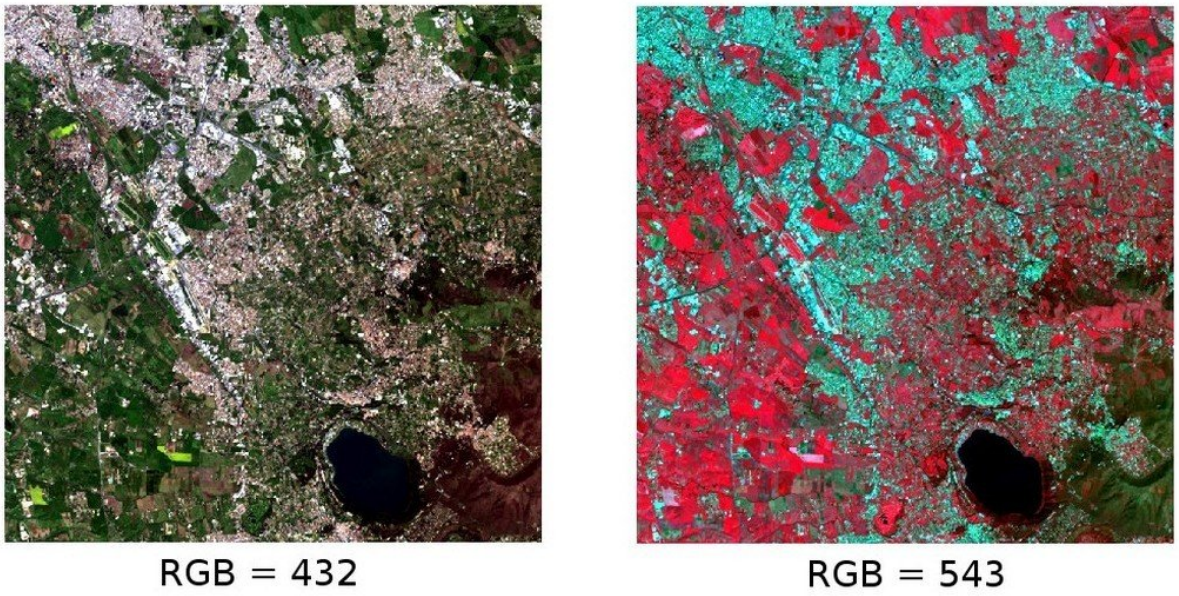


Fig. 6.3: *Color composite of a Landsat 8 image*
`Data available from the U.S. Geological Survey`

The following weights for I are defined, basing on several tests performed using the SCP. For Landsat 8, Intensity is calculated as:

$$I = (0.42 * Blueband + 0.98 * Greenband + 0.6 * Redband)/2$$

For Landsat 7, Intensity is calculated as:

$$I = (0.42 * Blueband + 0.98 * Greenband + 0.6 * Redband + NIRband)/3$$

Fig. 6.4: *Example of pan-sharpening of a Landsat 8 image. Left, original multispectral bands (30m); right, pan-sharpened bands (15m)*

Data available from the U.S. Geological Survey

CHAPTER 7

Supervised Classification Definitions

This chapter provides basic definitions about supervised classifications.

7.1 Land Cover

Land cover is the material at the ground, such as soil, vegetation, water, asphalt, etc. (Fisher and Unwin, 2005). Depending on the sensor resolutions, the number and kind of land cover classes that can be identified in the image can vary significantly.

7.2 Supervised Classification

A **semi-automatic classification** (also supervised classification) is an image processing technique that allows for the identification of materials in an image, according to their spectral signatures. There are several kinds of classification algorithms, but the general purpose is to produce a thematic map of the land cover.

Image processing and GIS spatial analyses require specific software such as the Semi-Automatic Classification Plugin for QGIS.

7.3 Training Areas

Usually, supervised classifications require the user to select one or more Regions of Interest (ROIs, also Training Areas) for each land cover class identified in the image. **ROIs** are polygons drawn over homogeneous areas of the image that overlay pixels belonging to the same land cover class.

7.4 Classes and Macroclasses

Land cover classes are identified with an arbitrary ID code (i.e. Identifier). SCP allows for the definition of **Macroclass ID** (i.e. MC ID) and **Class ID** (i.e. C ID), which are the identification codes of land cover classes. A **Macroclass** is a group of ROIs having different Class ID, which is useful when one needs to classify materials that have different spectral signatures in the same land cover class. For instance, one can identify grass (e.g. `ID class = 1` and `Macroclass ID = 1`) and trees (e.g. `ID class = 2` and `Macroclass ID = 1`) as vegetation class (e.g. `Macroclass ID = 1`). Multiple Class IDs can be assigned to the same Macroclass ID, but the same Class ID cannot be assigned to multiple Macroclass IDs, as shown in the following table.

Macroclass name	Macroclass ID	Class name	Class ID
Vegetation	1	Grass	1
Vegetation	1	Trees	2
Built-up	2	Road	3

Therefore, Classes are subsets of a Macroclass as illustrated in Figure *Macroclass example* (page 40).

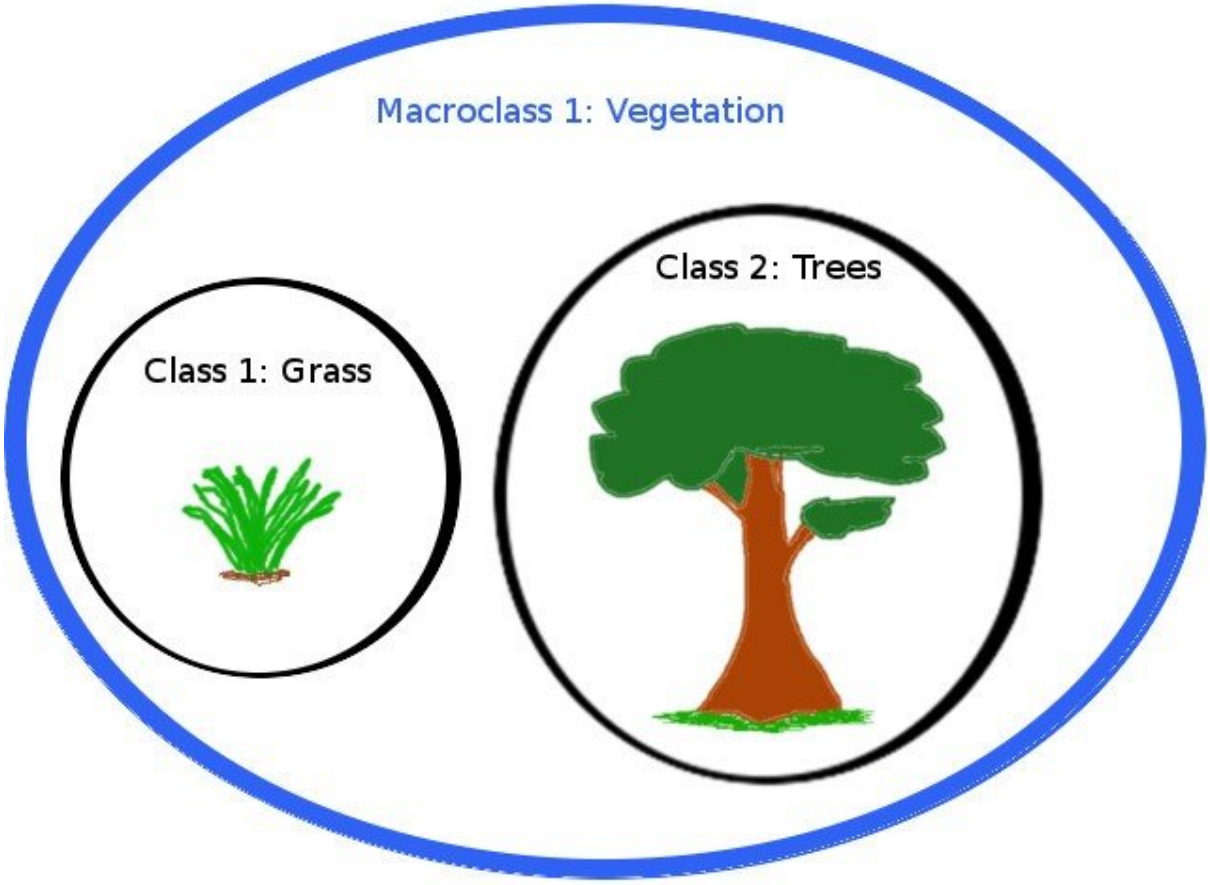


Fig. 7.1: *Macroclass example*

If the use of Macroclass is not required for the study purpose, then the same Macroclass ID can be defined for all the ROIs (e.g. Macroclass ID = 1) and Macroclass values are ignored in the classification process.

7.5 Classification Algorithms

The **spectral signatures** (spectral characteristics) of reference land cover classes are calculated considering the values of pixels under each ROI having the same Class ID (or Macroclass ID). Therefore, the classification algorithm classifies the whole image by comparing the spectral characteristics of each pixel to the spectral characteristics of reference land cover classes. SCP implements the following classification algorithms.

7.5.1 Minimum Distance

Minimum Distance algorithm calculates the Euclidean distance $d(x, y)$ between spectral signatures of image pixels and training spectral signatures, according to the following equation:

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

where:

- x = spectral signature vector of an image pixel;
- y = spectral signature vector of a training area;

- n = number of image bands.

Therefore, the distance is calculated for every pixel in the image, assigning the class of the spectral signature that is closer, according to the following discriminant function (adapted from Richards and Jia, 2006):

$$x \in C_k \iff d(x, y_k) < d(x, y_j) \forall k \neq j$$

where:

- C_k = land cover class k;
- y_k = spectral signature of class k;
- y_j = spectral signature of class j.

It is possible to define a threshold T_i in order to exclude pixels below this value from the classification:

$$x \in C_k \iff d(x, y_k) < d(x, y_j) \forall k \neq j$$
$$and$$
$$d(x, y_k) < T_i$$

7.5.2 Maximum Likelihood

Maximum Likelihood algorithm calculates the probability distributions for the classes, related to Bayes' theorem, estimating if a pixel belongs to a land cover class. In particular, the probability distributions for the classes are assumed the of form of multivariate normal models (Richards & Jia, 2006). In order to use this algorithm, a sufficient number of pixels is required for each training area allowing for the calculation of the covariance matrix. The discriminant function, described by Richards and Jia (2006), is calculated for every pixel as:

$$g_k(x) = \ln p(C_k) - \frac{1}{2} \ln |\Sigma_k| - \frac{1}{2}(x - y_k)^t \Sigma_k^{-1} (x - y_k)$$

where:

- C_k = land cover class k;
- x = spectral signature vector of a image pixel;
- $p(C_k)$ = probability that the correct class is C_k;
- $|\Sigma_k|$ = determinant of the covariance matrix of the data in class C_k;
- Σ_k^{-1} = inverse of the covariance matrix;
- y_k = spectral signature vector of class k.

Therefore:

$$x \in C_k \iff g_k(x) > g_j(x) \forall k \neq j$$

In addition, it is possible to define a threshold to the discriminant function in order to exclude pixels below this value from the classification. Considering a threshold T_i the classification condition becomes:

$$x \in C_k \iff g_k(x) > g_j(x) \forall k \neq j$$
$$and$$
$$g_k(x) > T_i$$

Maximum likelihood is one of the most common supervised classifications, however the classification process can be slower than *Minimum Distance* (page 40).

7.5.3 Spectra Angle Mapping

The Spectral Angle Mapping calculates the spectral angle between spectral signatures of image pixels and training spectral signatures. The spectral angle θ is defined as (Kruse et al., 1993):

$$\theta(x,y) = \cos^{-1}\left(\frac{\sum_{i=1}^{n} x_i y_i}{(\sum_{i=1}^{n} x_i^2)^{\frac{1}{2}} * (\sum_{i=1}^{n} y_i^2)^{\frac{1}{2}}}\right)$$

Where:

- x = spectral signature vector of an image pixel;
- y = spectral signature vector of a training area;
- n = number of image bands.

Therefore a pixel belongs to the class having the lowest angle, that is:

$$x \in C_k \iff \theta(x,y_k) < \theta(x,y_j) \forall k \neq j$$

where:

- C_k = land cover class k;
- y_k = spectral signature of class k;
- y_j = spectral signature of class j.

In order to exclude pixels below this value from the classification it is possible to define a threshold T_i:

$$x \in C_k \iff \theta(x,y_k) < \theta(x,y_j) \forall k \neq j$$
$$and$$
$$\theta(x,y_k) < T_i$$

Spectral Angle Mapping is largely used, especially with hyperspectral data.

7.6 Spectral Distance

It is useful to evaluate the spectral distance (or separability) between training signatures or pixels, in order to assess if different classes that are too similar could cause classification errors. The SCP implements the following algorithms for assessing similarity of spectral signatures.

7.6.1 Jeffries-Matusita Distance

Jeffries-Matusita Distance calculates the separability of a pair of probability distributions. This can be particularly meaningful for evaluating the results of *Maximum Likelihood* (page 41) classifications.

The Jeffries-Matusita Distance J_{xy} is calculated as (Richards and Jia, 2006):

$$J_{xy} = 2\left(1 - e^{-B}\right)$$

where:

$$B = \frac{1}{8}(x-y)^t \left(\frac{\Sigma_x + \Sigma_y}{2}\right)^{-1} (x-y) + \frac{1}{2}\ln\left(\frac{|\frac{\Sigma_x+\Sigma_y}{2}|}{|\Sigma_x|^{\frac{1}{2}}|\Sigma_y|^{\frac{1}{2}}}\right)$$

where:

- x = first spectral signature vector;
- y = second spectral signature vector;

- Σ_x = covariance matrix of sample x;
- Σ_y = covariance matrix of sample y;

The Jeffries-Matusita Distance is asymptotic to 2 when signatures are completely different, and tends to 0 when signatures are identical.

7.6.2 Spectral Angle

The Spectral Angle is the most appropriate for assessing the *Spectra Angle Mapping* (page 42) algorithm. The spectral angle θ is defined as (Kruse et al., 1993):

$$\theta(x,y) = \cos^{-1}\left(\frac{\sum_{i=1}^{n} x_i y_i}{(\sum_{i=1}^{n} x_i^2)^{\frac{1}{2}} * (\sum_{i=1}^{n} y_i^2)^{\frac{1}{2}}}\right)$$

Where:

- x = spectral signature vector of an image pixel;
- y = spectral signature vector of a training area;
- n = number of image bands.

Spectral angle goes from 0 when signatures are identical to 90 when signatures are completely different.

7.6.3 Euclidean Distance

The Euclidean Distance is particularly useful for the evaluating the result of *Minimum Distance* (page 40) classifications. In fact, the distance is defined as:

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

where:

- x = first spectral signature vector;
- y = second spectral signature vector;
- n = number of image bands.

The Euclidean Distance is 0 when signatures are identical and tends to increase according to the spectral distance of signatures.

7.6.4 Bray-Curtis Similarity

The Bray-Curtis Similarity is a statistic used for assessing the relationship between two samples (read this). It is useful in general for assessing the similarity of spectral signatures, and Bray-Curtis Similarity $S(x,y)$ is calculated as:

$$S(x,y) = 100 - \left(\frac{\sum_{i=1}^{n} |(x_i - y_i)|}{\sum_{i=1}^{n} x_i + \sum_{i=1}^{n} y_i}\right) * 100$$

where:

- x = first spectral signature vector;
- y = second spectral signature vector;
- n = number of image bands.

The Bray-Curtis similarity is calculated as percentage and ranges from 0 when signatures are completely different to 100 when spectral signatures are identical.

7.7 Classification Result

The result of the classification process is a raster (see an example of Landsat classification in Figure *Landsat classification* (page 44)), where pixel values correspond to class IDs and each color represent a land cover class.

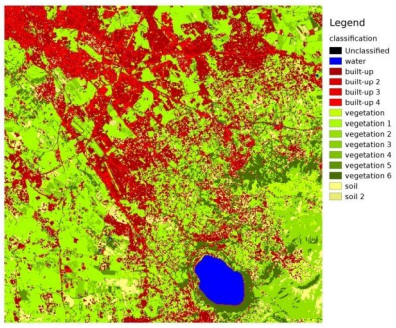


Fig. 7.2: *Landsat classification*
`Data available from the U.S. Geological Survey`

A certain amount of errors can occur in the land cover classification (i.e. pixels assigned to a wrong land cover class), due to spectral similarity of classes, or wrong class definition during the ROI collection.

7.8 Accuracy Assessment

After the classification process, it is useful to assess the accuracy of land cover classification, in order to identify and measure map errors. Usually, **accuracy assessment** is performed with the calculation of an error matrix, which is a table that compares map information with reference data (i.e. ground truth data) for a number of sample areas (Congalton and Green, 2009).

The following table is a scheme of error matrix, where k is the number of classes identified in the land cover classification, and n is the total number of collected sample units. The items in the major diagonal (aii) are the number of samples correctly identified, while the other items are classification error.

	Ground truth 1	Ground truth 2	...	Ground truth k	Total
Class 1	a_{11}	a_{12}	...	a_{1k}	a_{1+}
Class 2	a_{21}	a_{22}	...	a_{2k}	a_{2+}
...	...	...	...	...	...
Class k	a_{k1}	a_{k2}	...	a_{kk}	a_{k+}
Total	a_{+1}	a_{+2}	...	a_{+k}	n

Therefore, it is possible to calculate the overall accuracy as the ratio between the number of samples that are correctly classified (the sum of the major diagonal), and the total number of sample units n (Congalton and Green, 2009).

For further information, the following documentation is freely available: Landsat 7 Science Data User's Handbook, Remote Sensing Note , or Wikipedia.

References

- Congalton, R. and Green, K., 2009. Assessing the Accuracy of Remotely Sensed Data: Principles and Practices. Boca Raton, FL: CRC Press.
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CHAPTER 8

Landsat image conversion to reflectance and DOS1 atmospheric correction

This chapter provides information about the Landsat conversion to reflectance implemented in SCP *Landsat* (page 114).

Landsat images downloaded from http://earthexplorer.usgs.gov or through the SCP tool *Download Landsat* (page 108) are composed of several bands and a metadata file (MTL) which contains useful information about image data.

8.1 Radiance at the Sensor's Aperture

Radiance is the "flux of energy (primarily irradiant or incident energy) per solid angle leaving a unit surface area in a given direction", "Radiance is what is measured at the sensor and is somewhat dependent on reflectance" (NASA, 2011, p. 47).

The **Spectral Radiance at the sensor's aperture** (L_λ) is measured in [watts/(meter squared * ster * μm)] and for Landsat images it is given by (https://landsat.usgs.gov/Landsat8_Using_Product.php):

$$L_\lambda = M_L * Q_{cal} + A_L$$

where:

- M_L = Band-specific multiplicative rescaling factor from Landsat metadata (RADIANCE_MULT_BAND_x, where x is the band number)
- A_L = Band-specific additive rescaling factor from Landsat metadata (RADIANCE_ADD_BAND_x, where x is the band number)
- Q_{cal} = Quantized and calibrated standard product pixel values (DN)

8.2 Top Of Atmosphere (TOA) Reflectance

"For relatively clear Landsat scenes, a reduction in between-scene variability can be achieved through a normalization for solar irradiance by converting spectral radiance, as calculated above, to planetary reflectance or albedo. This combined **surface and atmospheric reflectance** of the Earth is computed with the following formula" (NASA, 2011, p. 119):

$$\rho_p = (\pi * L_\lambda * d^2)/(ESUN_\lambda * cos\theta_s)$$

where:

- ρ_p = Unitless TOA reflectance, which is "the ratio of reflected versus total power energy" (NASA, 2011, p. 47)
- L_λ = Spectral radiance at the sensor's aperture (at-satellite radiance)

- d = Earth-Sun distance in astronomical units (provided with Landsat 8 metafile, and an excel file is available from http://landsathandbook.gsfc.nasa.gov/excel_docs/d.xls)
- $ESUN_\lambda$ = Mean solar exo-atmospheric irradiances
- θ_s = Solar zenith angle in degrees, which is equal to θ_s = 90° - θ_e where θ_e is the Sun elevation

It is worth pointing out that Landsat 8 images are provided with band-specific rescaling factors that allow for the direct conversion from DN to TOA reflectance. However, the effects of the atmosphere (i.e. a disturbance on the reflectance that varies with the wavelength) should be considered in order to measure the reflectance at the ground.

8.3 Surface Reflectance

As described by Moran et al. (1992), the **land surface reflectance** (ρ) is:

$$\rho = [\pi * (L_\lambda - L_p) * d^2]/[T_v * ((ESUN_\lambda * cos\theta_s * T_z) + E_{down})]$$

where:

- L_p is the path radiance
- T_v is the atmospheric transmittance in the viewing direction
- T_z is the atmospheric transmittance in the illumination direction
- E_{down} is the downwelling diffuse irradiance

Therefore, we need several atmospheric measurements in order to calculate ρ (physically-based corrections). Alternatively, it is possible to use **image-based techniques** for the calculation of these parameters, without in-situ measurements during image acquisition. It is worth mentioning that Landsat Surface Reflectance High Level Data Products for Landsat 8 are available (for more information read http://landsat.usgs.gov/CDR_LSR.php).

8.4 DOS1 Correction

The **Dark Object Subtraction** (DOS) is a family of image-based atmospheric corrections. Chavez (1996) explains that "the basic assumption is that within the image some pixels are in complete shadow and their radiances received at the satellite are due to atmospheric scattering (path radiance). This assumption is combined with the fact that very few targets on the Earth's surface are absolute black, so an assumed one-percent minimum reflectance is better than zero percent". It is worth pointing out that the accuracy of image-based techniques is generally lower than physically-based corrections, but they are very useful when no atmospheric measurements are available as they can improve the estimation of land surface reflectance. The **path radiance** is given by (Sobrino, et al., 2004):

$$L_p = L_{min} - L_{DO1\%}$$

where:

- L_{min} = "radiance that corresponds to a digital count value for which the sum of all the pixels with digital counts lower or equal to this value is equal to the 0.01% of all the pixels from the image considered" (Sobrino, et al., 2004, p. 437), therefore the radiance obtained with that digital count value (DN_{min})
- $L_{DO1\%}$ = radiance of Dark Object, assumed to have a reflectance value of 0.01

Therfore for Landsat images:

$$L_{min} = M_L * DN_{min} + A_L$$

The **radiance of Dark Object** is given by (Sobrino, et al., 2004):

$$L_{DO1\%} = 0.01 * [(ESUN_\lambda * cos\theta_s * T_z) + E_{down}] * T_v/(\pi * d^2)$$

Therefore the **path radiance** is:

$$L_p = M_L * DN_{min} + A_L - 0.01 * [(ESUN_\lambda * cos\theta_s * T_z) + E_{down}] * T_v/(\pi * d^2)$$

There are several DOS techniques (e.g. DOS1, DOS2, DOS3, DOS4), based on different assumption about T_v, T_z , and E_{down} . The simplest technique is the **DOS1**, where the following assumptions are made (Moran et al., 1992):

- T_v = 1
- T_z = 1
- E_{down} = 0

Therefore the **path radiance** is:

$$L_p = M_L * DN_{min} + A_L - 0.01 * ESUN_\lambda * cos\theta_s / (\pi * d^2)$$

And the resulting **land surface reflectance** is given by:

$$\rho = [\pi * (L_\lambda - L_p) * d^2] / (ESUN_\lambda * cos\theta_s)$$

ESUN [W /(m2 * μm)] values for Landsat sensors are provided in the following table.

Band	Landsat 4*	Landsat 5**	Landsat 7**
1	1957	1983	1997
2	1825	1769	1812
3	1557	1536	1533
4	1033	1031	1039
5	214.9	220	230.8
7	80.72	83.44	84.90

* from Chander & Markham (2003)

** from Finn, et al. (2012)

For Landsat 8, $ESUN$ can be calculated as (from http://grass.osgeo.org/grass65/manuals/i.landsat.toar.html):

$$ESUN = (\pi * d^2) * RADIANCE\_MAXIMUM / REFLECTANCE\_MAXIMUM$$

where RADIANCE_MAXIMUM and REFLECTANCE_MAXIMUM are provided by image metadata.

An example of comparison of to TOA reflectance, DOS1 corrected reflectance and the Landsat Surface Reflectance High Level Data Products (ground truth) is provided in Figure *Spectral signatures of a built-up pixel* (page 49).

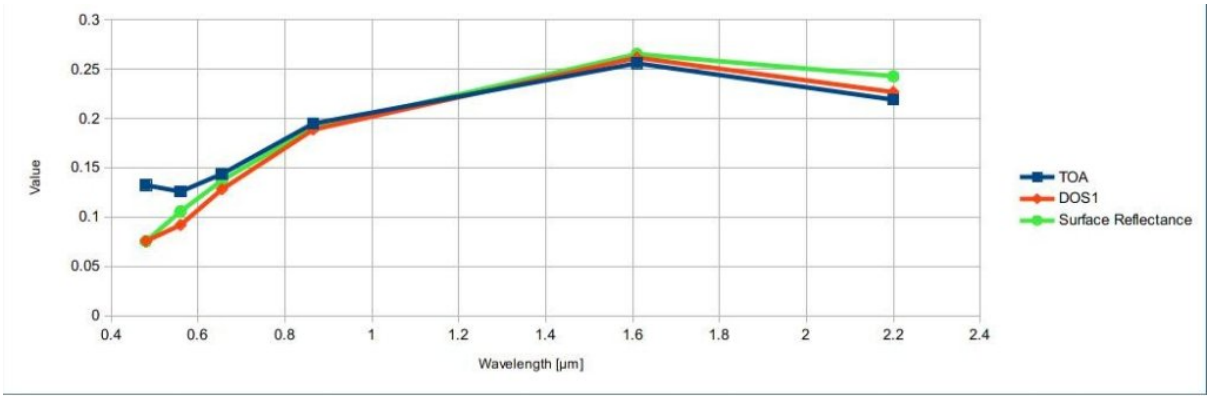

Fig. 8.1: *Spectral signatures of a built-up pixel*
`Comparison of TOA reflectance, DOS1 corrected reflectance and Landsat Surface Reflectance High Level Data Products`

References

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- NASA (Ed.) 2011. Landsat 7 Science Data Users Handbook Landsat Project Science Office at NASA's Goddard Space Flight Center in Greenbelt, 186 http://landsathandbook.gsfc.nasa.gov/pdfs/Landsat7_Handbook.pdf
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CHAPTER 9

Conversion to At-Satellite Brightness Temperature

This chapter provides information about the Landsat conversion to **At-Satellite Brightness Temperature** implemented in SCP *Landsat* (page 114). For information about how to estimate surface temperature read this post .

For Landsat thermal bands, the conversion of DN to At-Satellite Brightness Temperature is given by (from https://landsat.usgs.gov/Landsat8_Using_Product.php):

$$T_B = K_2/ln[(K_1/L_\lambda) + 1]$$

where:

- K_1 = Band-specific thermal conversion constant (in watts/meter squared * ster * μm)
- K_2 = Band-specific thermal conversion constant (in kelvin)

and L_λ is the Spectral Radiance at the sensor's aperture, measured in watts/(meter squared * ster * μm); for Landsat images it is given by (from https://landsat.usgs.gov/Landsat8_Using_Product.php):

$$L_\lambda = M_L * Q_{cal} + A_L$$

where:

- M_L = Band-specific multiplicative rescaling factor from Landsat metadata (RADIANCE_MULT_BAND_x, where x is the band number)
- A_L = Band-specific additive rescaling factor from Landsat metadata (RADIANCE_ADD_BAND_x, where x is the band number)
- Q_{cal} = Quantized and calibrated standard product pixel values (DN)

The K_1 and K_2 constant for Landsat sensors are provided in the following table:

Constant	Landsat 4*	Landsat 5*	Landsat 7**
K_1 (watts/meter squared * ster * μm)	671.62	607.76	666.09
K_2 (Kelvin)	1284.30	1260.56	1282.71

* from Chander & Markham (2003)

** from NASA (2011)

For Landsat 8, the K_1 and K_2 values are provided in the image metafile.

References

- Chander, G. & Markham, B. 2003. Revised Landsat-5 TM radiometric calibration procedures and postcalibration dynamic ranges Geoscience and Remote Sensing, IEEE Transactions on, 41, 2674 - 2677
- NASA (Ed.) 2011. Landsat 7 Science Data Users Handbook Landsat Project Science Office at NASA's Goddard Space Flight Center in Greenbelt, 186 http://landsathandbook.gsfc.nasa.gov/pdfs/Landsat7_Handbook.pdf

Part III

Basic Tutorials

Following, the list of basic tutorials that guide you through the steps of a land cover classification:

- *Tutorial 1: Your First Land Cover Classification* (page 57)
  - *Data* (page 57)
  - *Load Data* (page 57)
  - *Set the Input Image in SCP* (page 58)
  - *Create the Training Shapefile and Signature List File* (page 58)
  - *Create the ROIs* (page 58)
  - *Create a Classification Preview* (page 61)
  - *Create the Classification Output* (page 61)
- *Tutorial 2: Land Cover Classification of Landsat Images* (page 65)
  - *Data Download* (page 65)
  - *Automatic Conversion to Surface Reflectance* (page 66)
  - *Clip Data* (page 69)
  - *Create the Band Set* (page 71)
  - *Open the Training Shapefile and Signature List File* (page 71)
  - *Create the ROIs* (page 73)
  - *Create a Classification Preview* (page 78)
  - *Assess Spectral Signatures* (page 78)
  - *Create the Classification Output* (page 79)
- *Other Tutorials* (page 81)

CHAPTER 10

Tutorial 1: Your First Land Cover Classification

This is a basic tutorial about the use of the Semi-Automatic Classification Plugin (SCP) for the classification of a generic image. It is worth noticing that the image is multi-spectral. It is recommended to read the *Brief Introduction to Remote Sensing* (page 29) before this tutorial.

In this tutorial we are going to classify a remote sensing image acquired over Frascati (Rome, Italy) in order to identify the following land cover classes:

1. Water;
2. Built-up;
3. Vegetation;
4. Bare soil.

Following the video of this tutorial.

http://www.youtube.com/watch?v=nZffzX_sMnk

Alternative video link https://archive.org/details/video_basic_tutorial_1

10.1 Data

Download the image data from here (data available from the U.S. Geological Survey). It is a Landsat image, but in this tutorial we are going to use this raster as a generic dataset. For a specific tutorial about Landsat images read *Tutorial 2: Land Cover Classification of Landsat Images* (page 65) .

Unzip the downloaded file in a directory of your choice. The dataset is a multi-spectral raster (the file `sample_image.tif`) that includes the following Landsat bands:

1. Blue;
2. Green;
3. Red;
4. Near-Infrared;
5. Short Wavelength Infrared 1;
6. Short Wavelength Infrared 2.

10.2 Load Data

Start QGIS and load `sample_image.tif` in QGIS (from the QGIS menu `Layer > Add Raster Layer`). The image is displayed in QGIS.

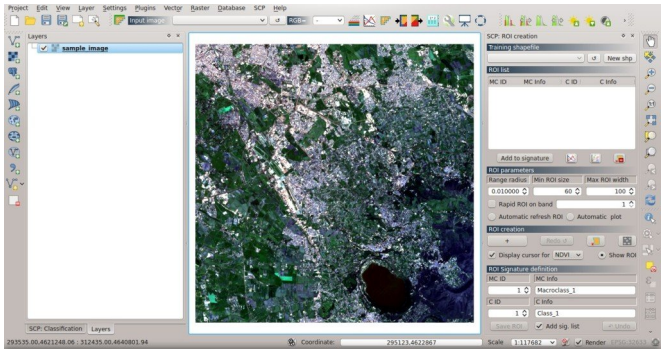


Fig. 10.1: *Image loaded in QGIS*

10.3 Set the Input Image in SCP

In the SCP *Toolbar* (page 87) click the button for refreshing the list `Input image` . In the list `Input image` select `sample_image` .

In the list `RGB` select the item `4-3-2` for displaying a *Color Composite* (page 35) of Near-Infrared, Red, and Green. The image in QGIS will be updated accordingly.

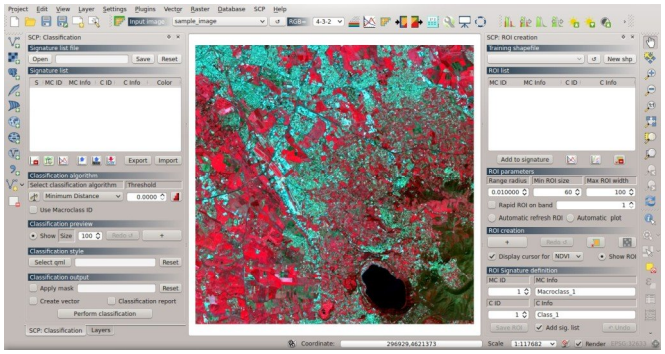


Fig. 10.2: *Color composite RGB=4-3-2 of Input image*

10.4 Create the Training Shapefile and Signature List File

In order to collect *Training Areas* (page 39) (ROIs) and calculate the *Spectral Signature* (page 33) thereof, we need to create the `Training shapefile` and `Signature list file` in SCP.

In the *ROI Creation dock* (page 89) click the button `New shp` and define a name (e.g. `ROI.shp`) in order to create the `Training shapefile` that will store ROI polygons. The shapefile is created and added to QGIS. The name of the `Training shapefile` is displayed in *Training shapefile* (page 89) .

Also, click the button `Save` in the *Classification dock* (page 95) and define a name (e.g. `SIG.xml`) in order to create the `Signature list file` that will store spectral signatures. The path of the `Signature list file` is displayed in *Signature list file* (page 95) .

10.5 Create the ROIs

We are going to create ROIs defining the *Classes and Macroclasses* (page 39) . The Macroclass ID codes are illustrated in the following table (of course, one can define different codes and classes according to the needs).

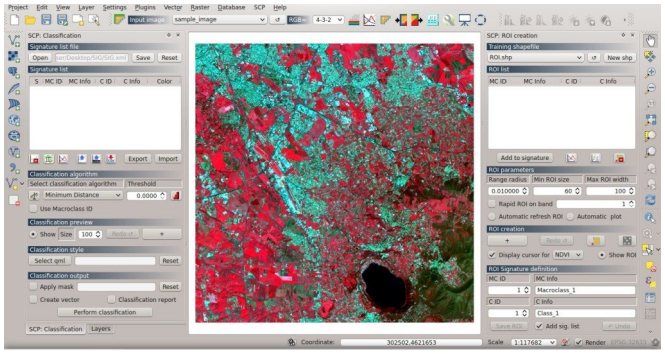


Fig. 10.3: *Definition of Training shapefile and Signature list file in SCP*

Macroclass name	Macroclass ID
Water	1
Built-up	2
Vegetation	3
Bare soil	4

ROIs can be created by manually drawing a polygon or with an automatic region growing algorithm.

Zoom in the map over the dark area (it is a lake) in the lower right region of the image. In order to create manually a ROI inside the dark area, click the button in the *ROI creation* (page 92) . Left click on the map to define the ROI vertices and right click to define the last vertex closing the polygon. An orange semi-transparent polygon is displayed over the image, which is a temporary polygon (i.e. it is not a shapefile).

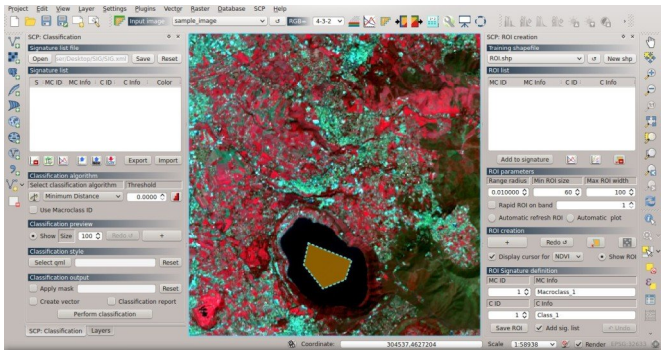


Fig. 10.4: *A temporary ROI created manually*

It is required to define the *Classes and Macroclasses* (page 39) . In the *ROI Signature definition* (page 93) set `MC ID` = 1 and `MC Info` = "Water" ; also set `C ID` = 1 and `C Info` = "Lake".

In order to save the polygon in the `Training shapefile` click the button `Save ROI` . After a few seconds, the ROI is listed in the *ROI list* (page 91) . Also, the spectral signature is calculated and listed in *Signature list* (page 95) (because `Add sig. list` was checked in *Classes and Macroclasses* (page 39)).

Now we have created the first ROI. Zoom in the map over the blue area (it is built-up) in the upper left region of the image. In order to create a ROI with the automatic region growing algorithm, in *ROI parameters* (page 91) set the `Range radius` value to 2000 (this value depends on image range of pixel values). It is possible to increase or decrease this value in order to create large or small ROIs. Click the button + in the *ROI creation* (page 92) and click over the blue area of the map. After a few moments the orange semi-transparent polygon is displayed over the image.

In the *ROI Signature definition* (page 93) set `MC ID` = 2 and `MC Info` = "Built-up" ; also set `C ID` = 2 and `C Info` = "Buildings".

Create a ROI for the class `Vegetation` (red areas) and a ROI for the class `Bare soil` (green areas) following

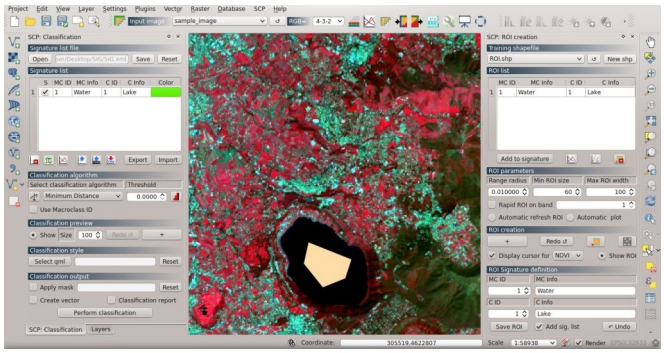


Fig. 10.5: *The ROI saved in the Training shapefile and the corresponding spectral signature displayed in the Signature list*

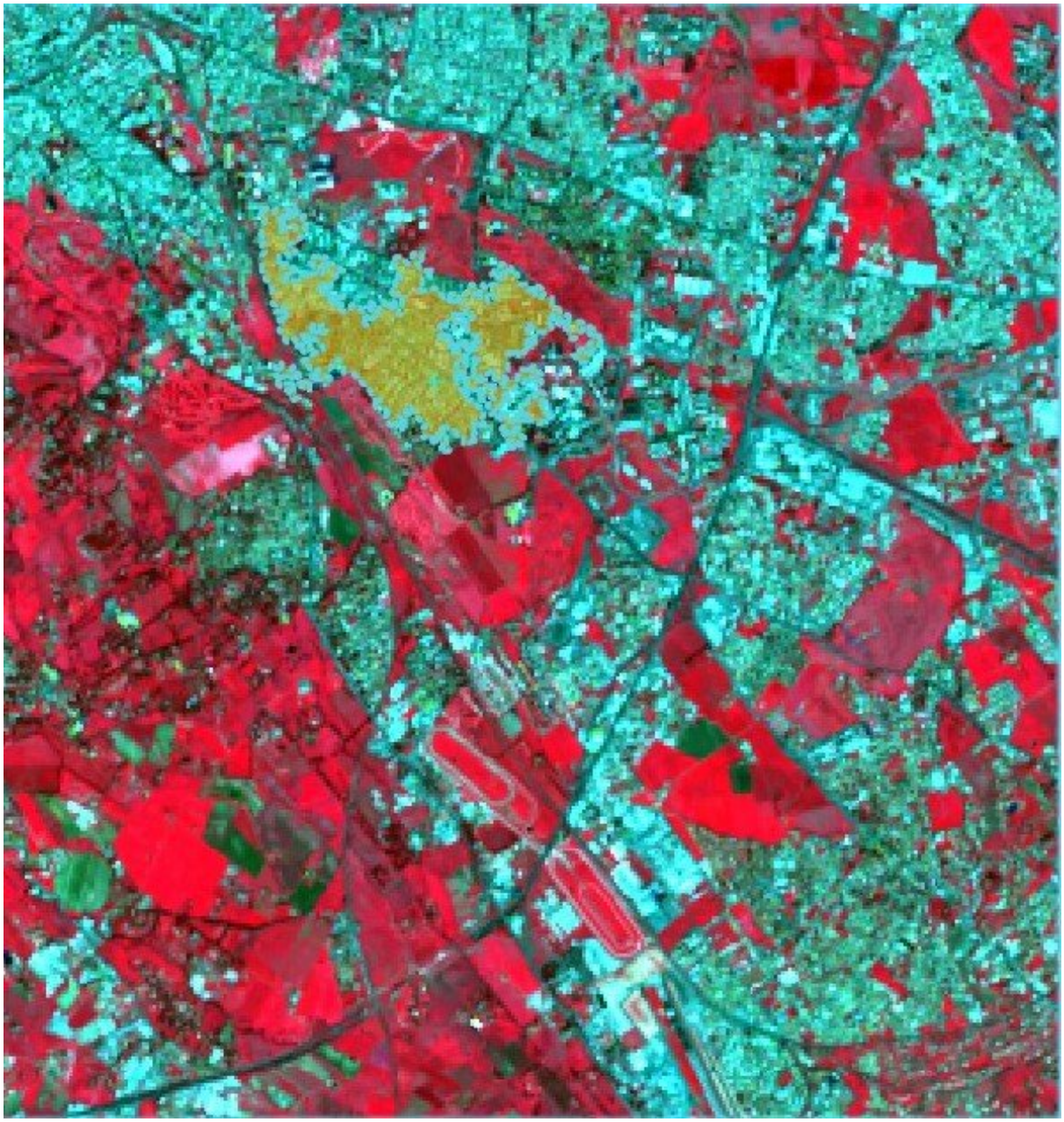


Fig. 10.6: *A temporary ROI created with the automatic region growing algorithm*

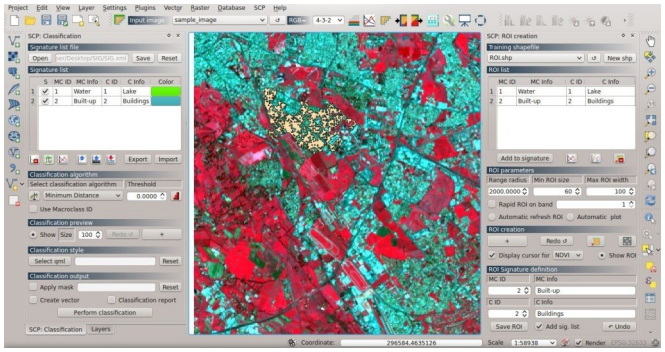


Fig. 10.7: *The ROI saved in the Training shapefile and the corresponding spectral signature displayed in the Signature list*

the same steps described previously. The following images show a few examples of these classes identified in the map.

10.6 Create a Classification Preview

It is useful to create a *Classification preview* (page 98) in order to assess the results before the final classification.

Set the colors of the spectral signatures, which will represent classes in the classification output: in the *Signature list* (page 95) double click the color in the column `Color` and choose a representative color of each class.

In the *Classification algorithm* (page 97) select the classification algorithm `Spectral Angle Mapping` that we are going to use in this tutorial. In *Classification preview* (page 98) set `Size` = 500 , click the button + and then left click the image in the map in order to create a classification preview. The result is a square in the map which represent the classification output.

Previews are temporary classifications and are useful for assessing the effects of spectral signatures during the ROI collection. Previews are placed in a group named `Class_temp_group` in the QGIS panel Layers.

In general, it is good to perform a classification preview every time a ROI (or a spectral signature) is added to the list. Therefore, the phases *Create the ROIs* (page 58) and *Create a Classification Preview* (page 61) should be iterative and concurrent processes.

10.7 Create the Classification Output

Assuming that the results of classification previews were good (i.e. classes were identified correctly), it is possible to perform the actual land cover classification of the whole image.

In the *Classification output* (page 99) click the button `Perform classification` and define the name of the classification output. The classification output is a raster file (.tif) where each pixel value corresponds to a land cover class (defined in the *Signature list* (page 95)).

Well done! You have just performed your first land cover classification. However, you can see that there are several classification errors (especially soil classified as built-up and vice versa), because the number of ROIs (spectral signatures) is insufficient.

In the following *Tutorial 2: Land Cover Classification of Landsat Images* (page 65) we are going to create more ROIs and improve the classification results.

Fig. 10.8: *Vegetation*

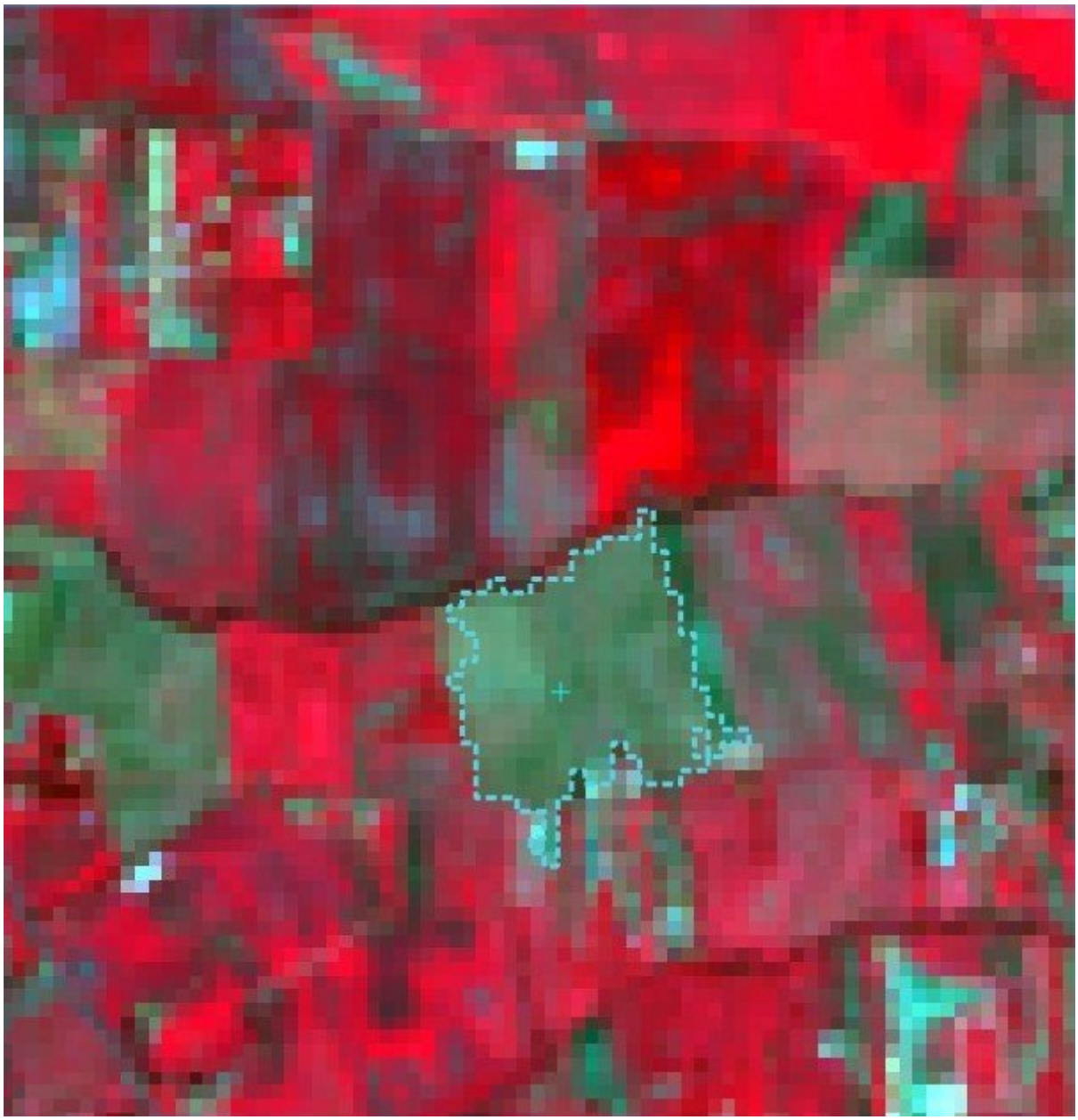


Fig. 10.9: *Bare soil*

TIP : The region growing algorithm can create more homogeneous spectral signatures than ROI created manually, which is good for the use of the algorithm `Spectral Angel Mapping` and `Maximum Likelihood`. The manual creation of ROIs can be useful in order to account for the spectral variability of a class, especially when using the algorithm `Maximum Likelihood`.

Fig. 10.10: *Definition of class colors in the table Signature list*

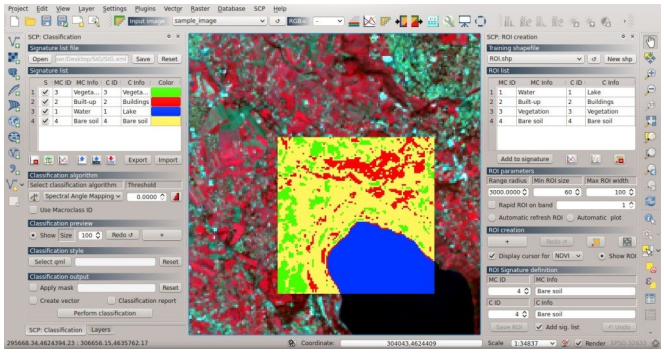


Fig. 10.11: *Classification preview displayed over the image*

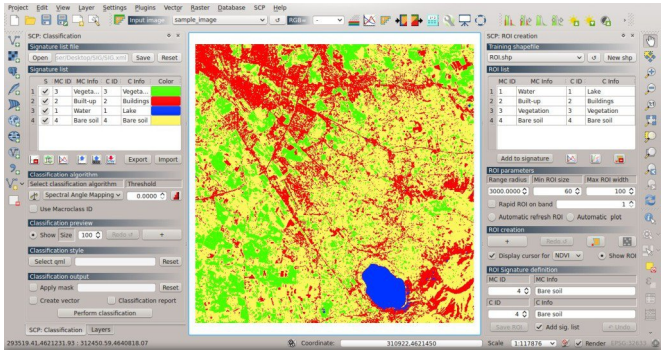


Fig. 10.12: *Result of the land cover classification*

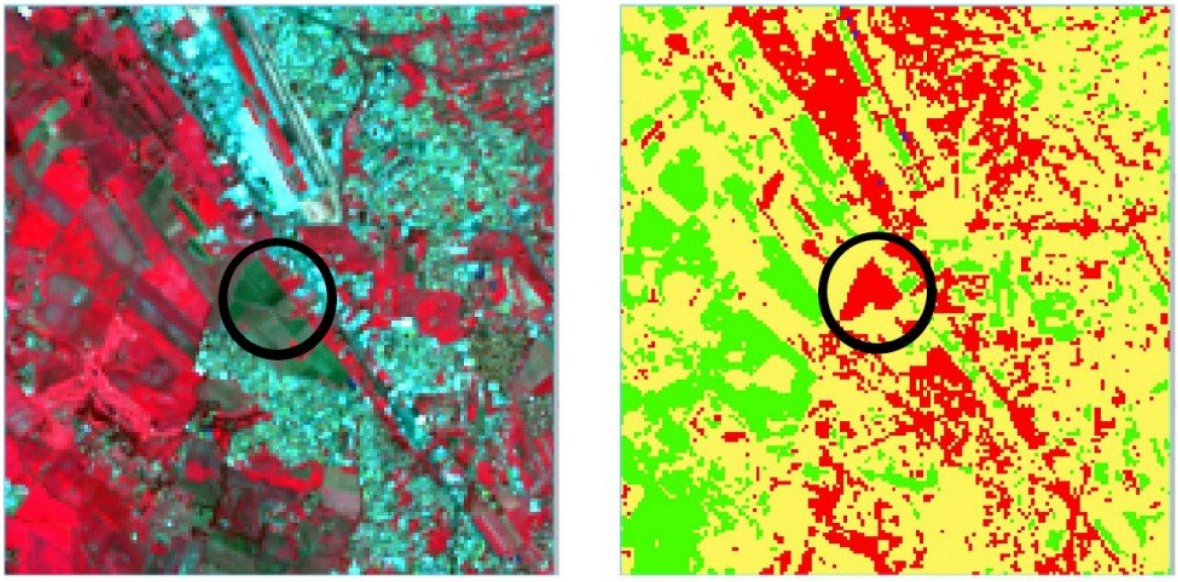


Fig. 10.13: *Example of error: Bare soil classified as Built-up*

CHAPTER 11

Tutorial 2: Land Cover Classification of Landsat Images

This tutorial describes the main phases for the classification of images acquired by *Landsat Satellite* (page 34) . In addition, some of the SCP tools are illustrated.

In this tutorial we are going to classify a Landsat 8 image acquired over Frascati (Rome, Italy) in order to identify the following land cover classes:

1. Water;
2. Built-up;
3. Vegetation;
4. Bare soil.

Following the video of this tutorial.

http://www.youtube.com/watch?v=ImbYhiIgl1g

Alternative video link https://archive.org/details/video_basic_tutorial_2

11.1 Data Download

We are going to **download the Landsat 8 image** using the SCP tool *Download Landsat* (page 108). The dataset we are going to download is a Landsat 8 image that includes the metadata file (the file LC81910312015006LGN00_MTL.txt) and the following Landsat 8 bands (for more information read *Landsat Satellite* (page 34)) :

- LC81910312015006LGN00_B2.tif = Blue;
- LC81910312015006LGN00_B3.tif = Green;
- LC81910312015006LGN00_B4.tif = Red;
- LC81910312015006LGN00_B5.tif = Near-Infrared;
- LC81910312015006LGN00_B6.tif = Short Wavelength Infrared 1;
- LC81910312015006LGN00_B7.tif = Short Wavelength Infrared 2.

Landsat images are available from the U.S. Geological Survey, and these bands are downloaded through the Amazon Web Services.

Start a new QGIS project. Open the tab *Download Landsat* (page 108) clicking the button in the *SCP menu* (page 85) or the *Toolbar* (page 87).

First, we need to download the Landsat database. Click the button `Select database directory` in order to define where to save the database. It is preferable to create a new directory (e.g. `LandsatDB`) in the user directory. Check the option `only Landsat 8` in order to download the database of Landsat 8 only. Click the button `Update database` and click `Yes` in the following question about updating the image database.

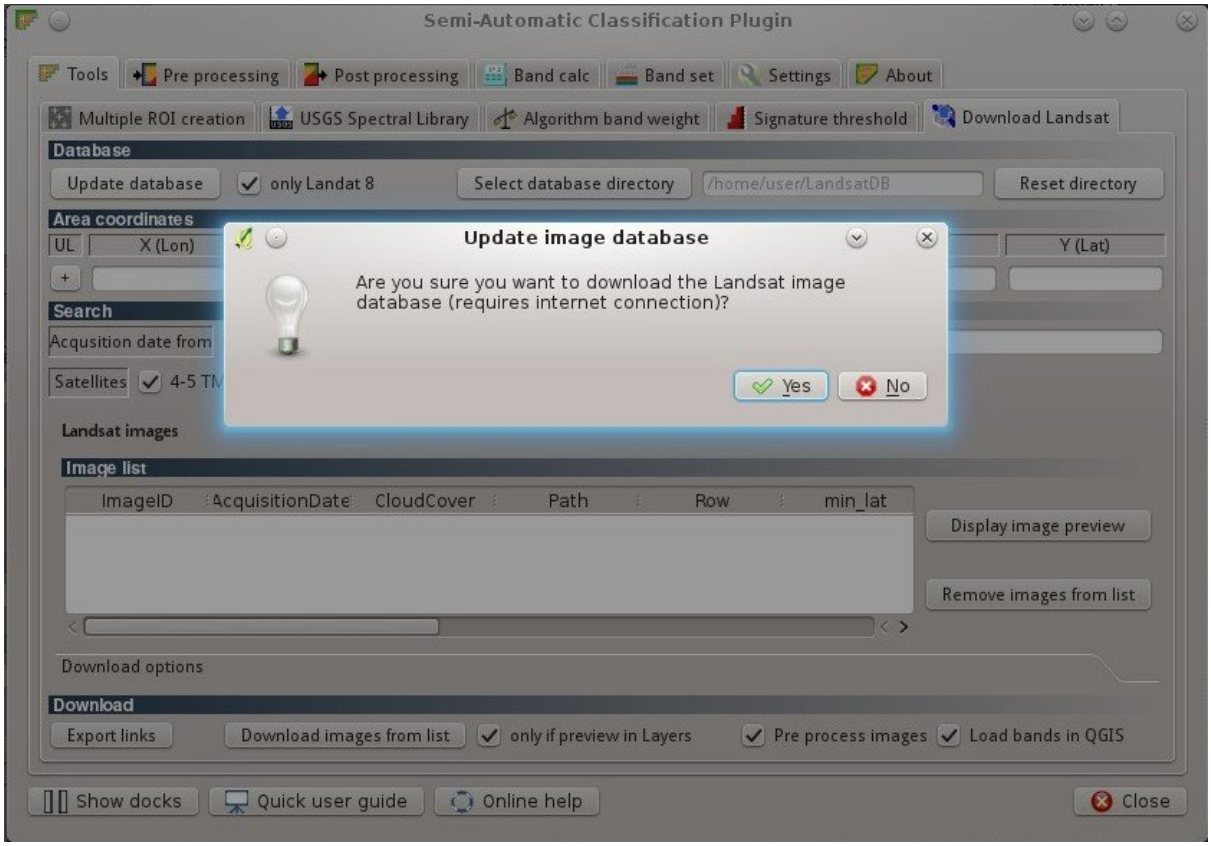


Fig. 11.1: *Download Landsat 8 database*

The download should start (about 7 MB).

When the download is completed, in the search box `Image ID` paste the Landsat ID: `LC81910312015006LGN00` . Now click the button `Find images` and after a few seconds the image will be listed in the `Image list`.

Click the tab `Download options` and leave checked only bands from 2 to 7 (we don't need the other bands for this tutorial). Also, uncheck all the options `only if preview in Layers`, `Pre process images`, and `Load bands in QGIS` (we are going to see these functions in other tutorials).

In order to start the image download, click the button `Download images from list` and select a directory where bands are saved (i.e. `Desktop`). The download could last a few minutes according to your internet connection speed (each Landsat band is about 50MB). The progress bar inform you about the downloading process. After the download, all the bands and the metadata file are saved in a new directory `LC81910312015006LGN00` (i.e. the Landsat ID) created automatically.

11.2 Automatic Conversion to Surface Reflectance

The metadata file contains information that is useful for the automatic conversion of bands to *Radiance and Reflectance* (page 33) . Read *Landsat image conversion to reflectance and DOS1 atmospheric correction* (page 47) for information about the calculation.

In order to convert automatically Landsat bands to reflectance, open the tab *Landsat* (page 114) clicking the button in the *SCP menu* (page 85) or the *Toolbar* (page 87) .

Click the button `Select directory` and select the `Directory containing Landsat bands` (i.e. the directory `LC81910312015006LGN00`). The list of bands will be automatically loaded in the table *Metadata*

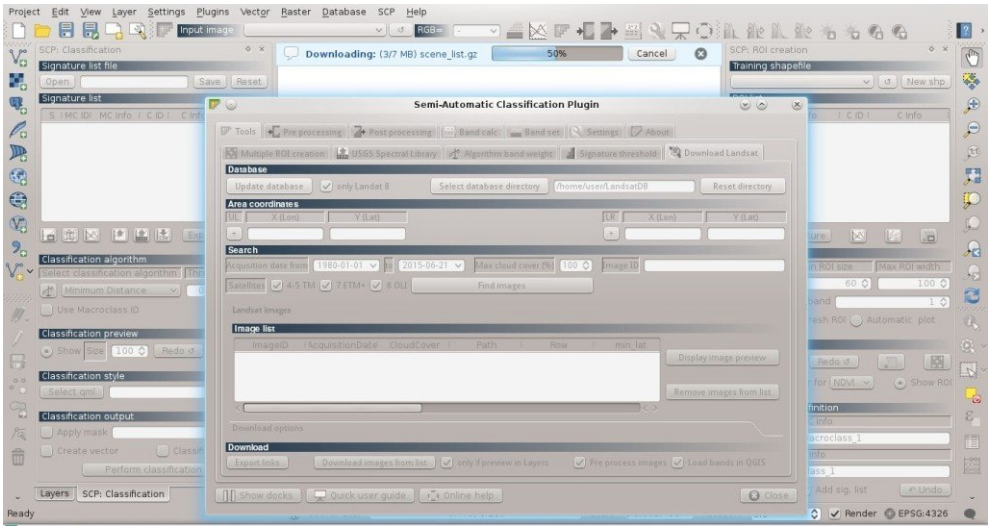


Fig. 11.2: *Downloading Landsat 8 database*

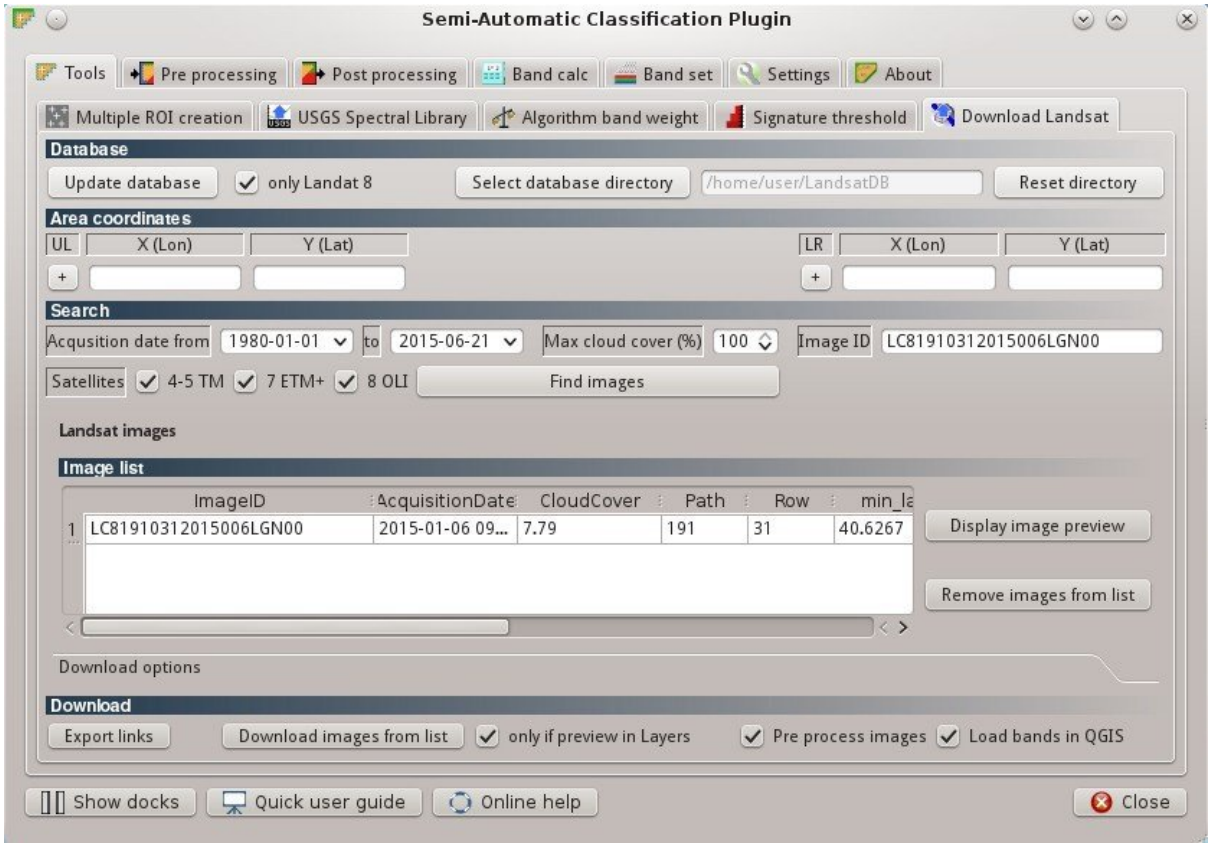


Fig. 11.3: *Search Landsat 8 image*

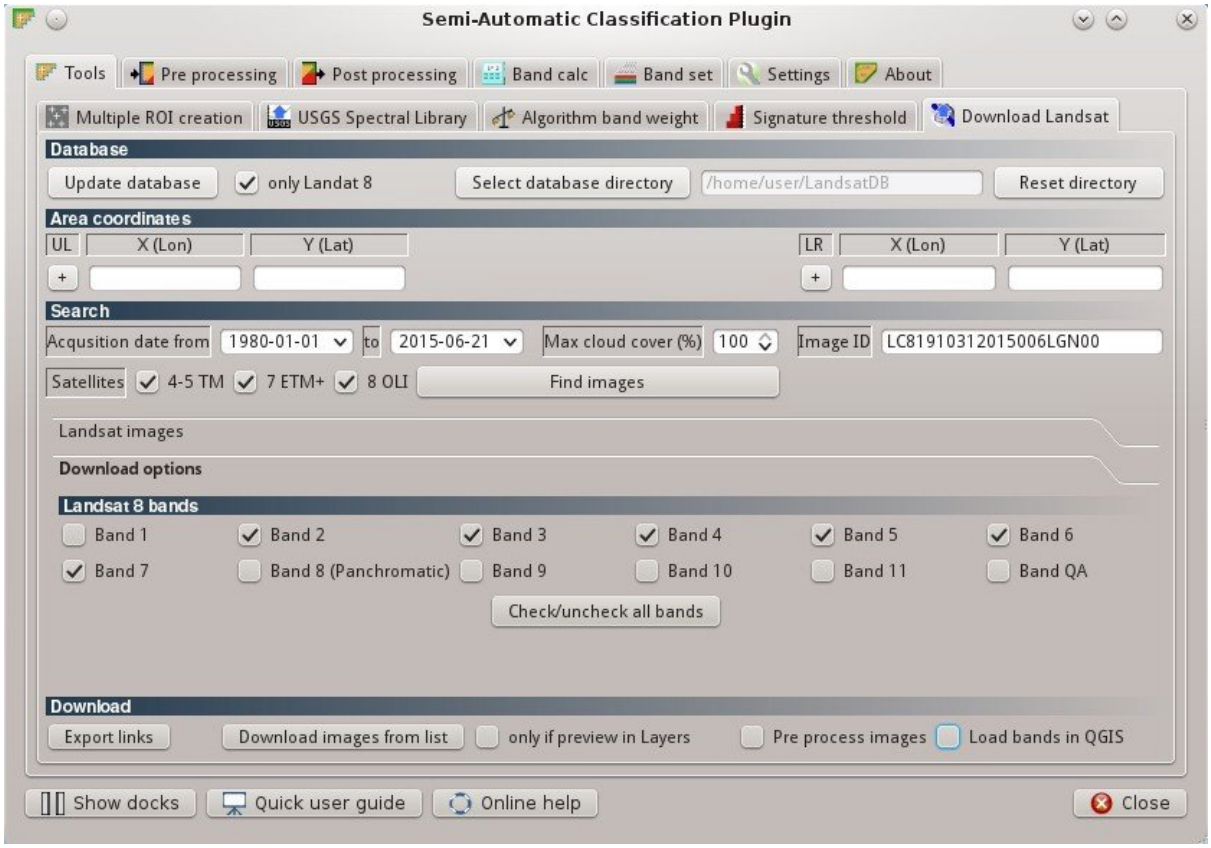


Fig. 11.4: *Select Landsat 8 bands for download*

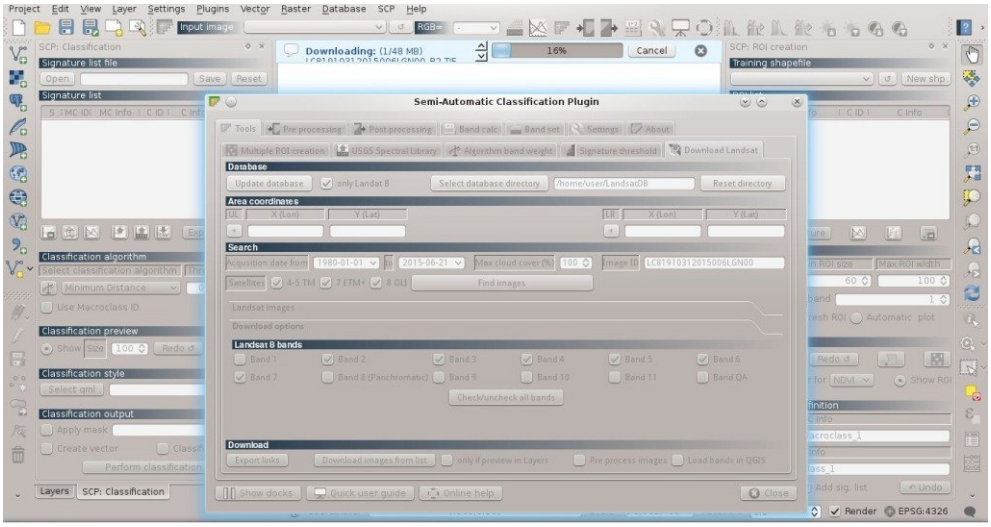


Fig. 11.5: *Download Landsat 8 bands*

(page 115) . Also, the metadata information for each band is loaded (because the metadata file MTL.txt is inside the same directory).

> **TIP** : If the metadata file MTL.txt was in a different directory, one can click the button `Select MTL file` and select the file. Also, it is possible to edit the metadata information inside the table *Metadata* (page 115) .

In order to calculate surface reflectance we are going to apply the *DOS1 Correction* (page 48) ; therefore, enable the option `Apply DOS1 atmospheric correction` .

> **TIP** : It is recommended to perform the DOS1 atmospheric correction to the entire Landsat image (before clipping the image) in order to improve the calculation of parameters based on the image.

Uncheck the option `Create Band set` (already enabled). In order to start the conversion process, click the button `Perform conversion` and select the directory where converted bands are saved (e.g. `LandsatRT`).

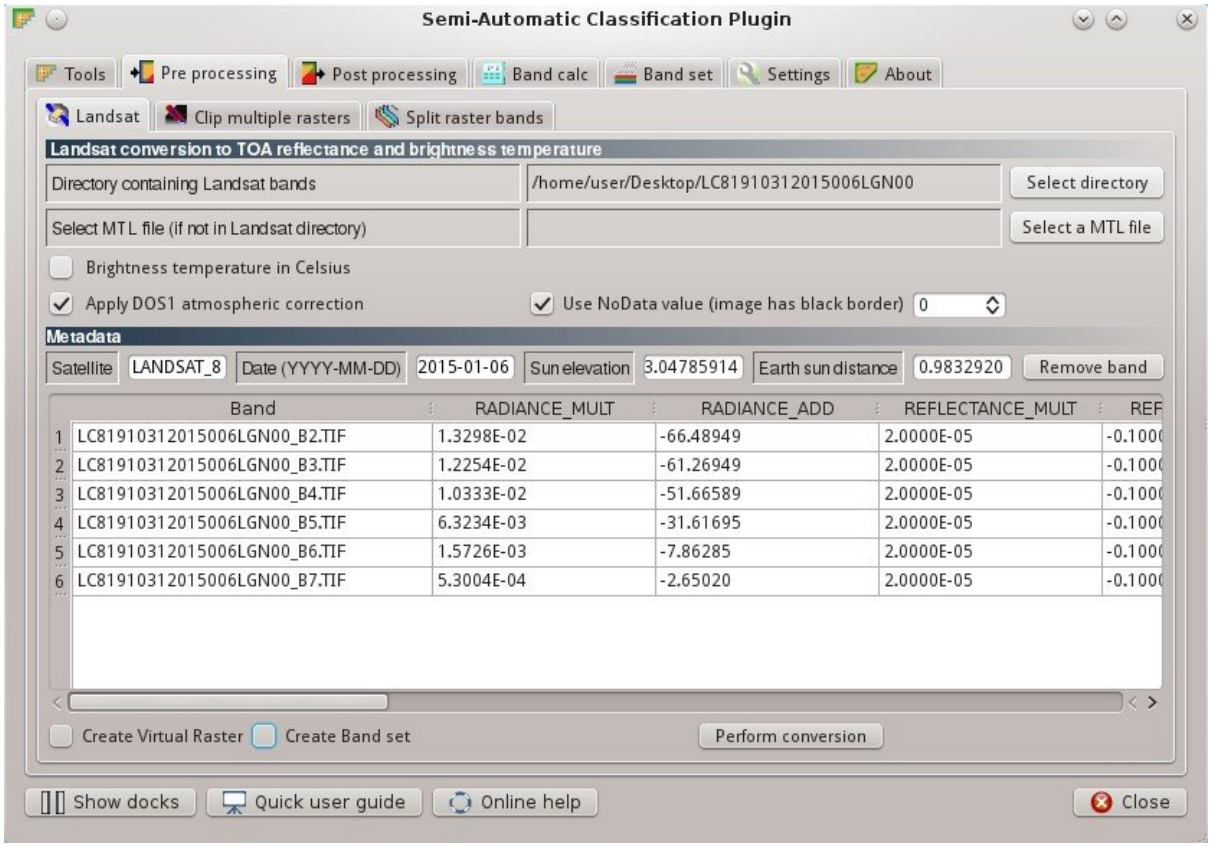


Fig. 11.6: *Landsat conversion to reflectance*

After a few minutes, converted bands are loaded in QGIS.

11.3 Clip Data

We are going to clip Landsat bands to our study area (of course this is optional in case the study is focused on a certain area of the image). Download the shapefile of the study area from here . Unzip the file and load the shapefile `study_area_Frascati` in QGIS.

Open the tab *Clip multiple rasters* (page 116) clicking the button in the *SCP menu* (page 85) or the *Toolbar* (page 87) . Under `Raster list` , click the button `Refresh list` and the Landsat bands loaded in QGIS will be listed in the table. Click the button `Select all` in order to clip all the images. Under `Clip coordinates`, check `Use shapefile for clipping` and click the button `Refresh list` in order

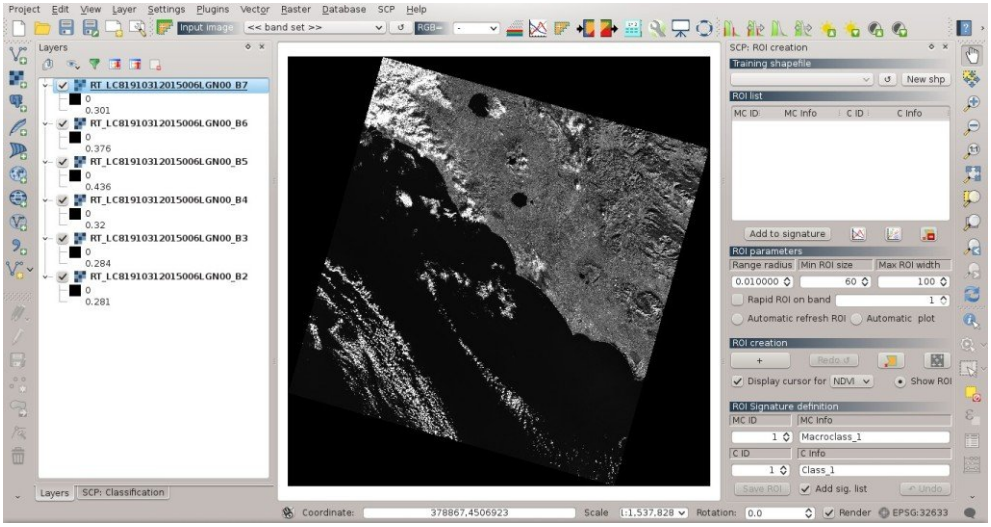


Fig. 11.7: *Converted Landsat bands*

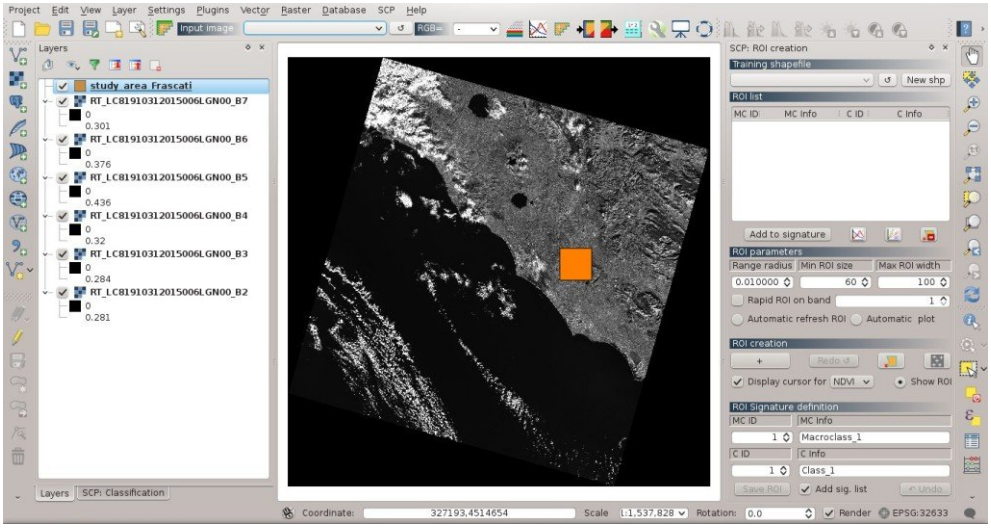


Fig. 11.8: *The study area shapefile*

to see the shapefile in the list. Click the button `Clip selected rasters` and select a directory (e.g. `Landsat_clip`) where clipped bands are saved (with the file name prefix `clip_`).

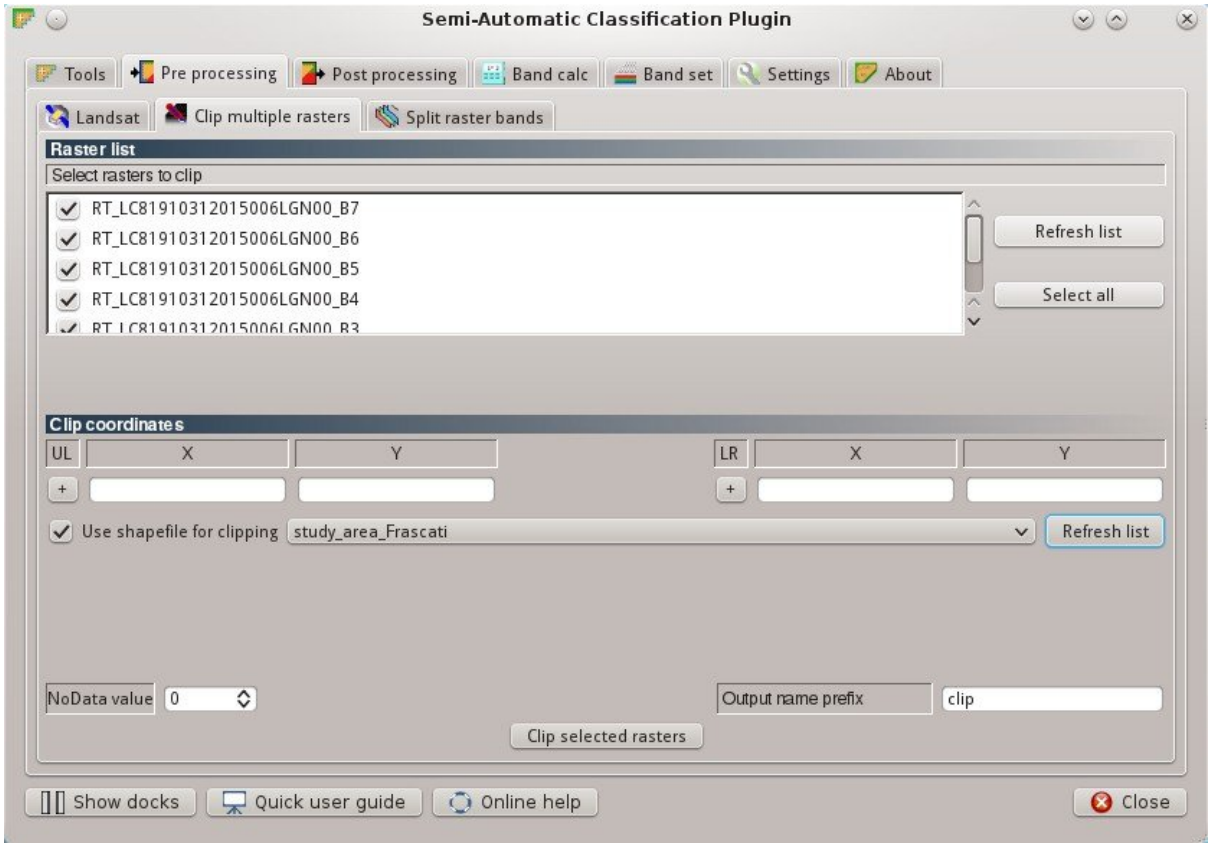


Fig. 11.9: *The tool for clipping the bands with the shapefile*

When the process is completed, clipped rasters are loaded in QGIS. We can remove the original Landsat bands from QGIS.

11.4 Create the Band Set

Now we need to define the `Band set` which is the input image for SCP. Open the tab *Band set* (page 127) clicking the button in the *SCP menu* (page 85) or the *Toolbar* (page 87). Click the button `Select All`, then `Add rasters to set` (order the band names in ascending order, from top to bottom, using the arrow buttons). Finally, select `Landsat 8 OLI` from the combo box `Quick wavelength settings`, in order to set automatically the center wavelength of each band (this is required for the spectral signature calculation).

You can notice that the item `<< band set >>` is selected as `Input image` in the *Toolbar* (page 87).

11.5 Open the Training Shapefile and Signature List File

We are going to open the `Training Shapefile` and `Signature list file` already created in *Tutorial 1: Your First Land Cover Classification* (page 57). If you don't have these files, follow the instructions *Create the Training Shapefile and Signature List File* (page 58).

Load in QGIS the `Training shapefile` saved previously (e.g. `ROI.shp`) from the QGIS menu `Layer > Add Vector Layer`. The shapefile is displayed in QGIS.

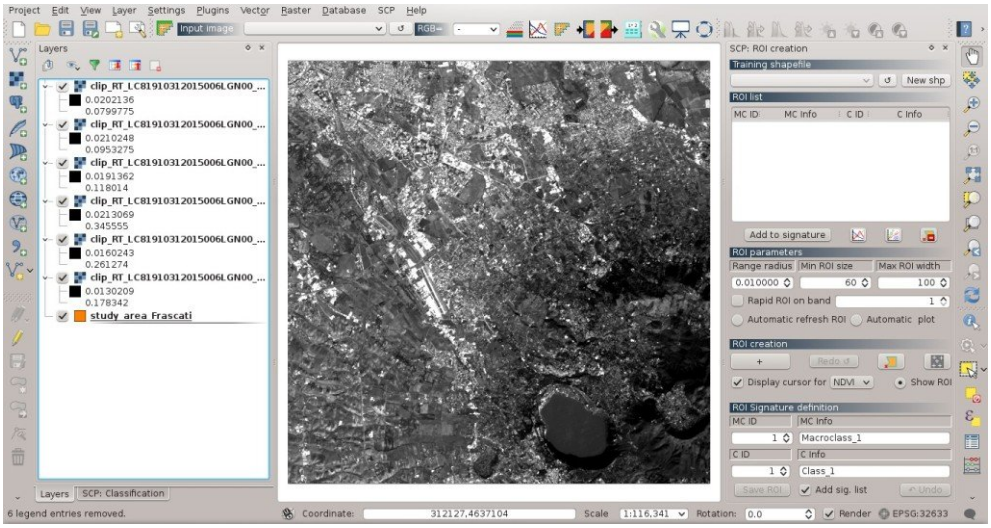


Fig. 11.10: *Clipped Landsat bands*

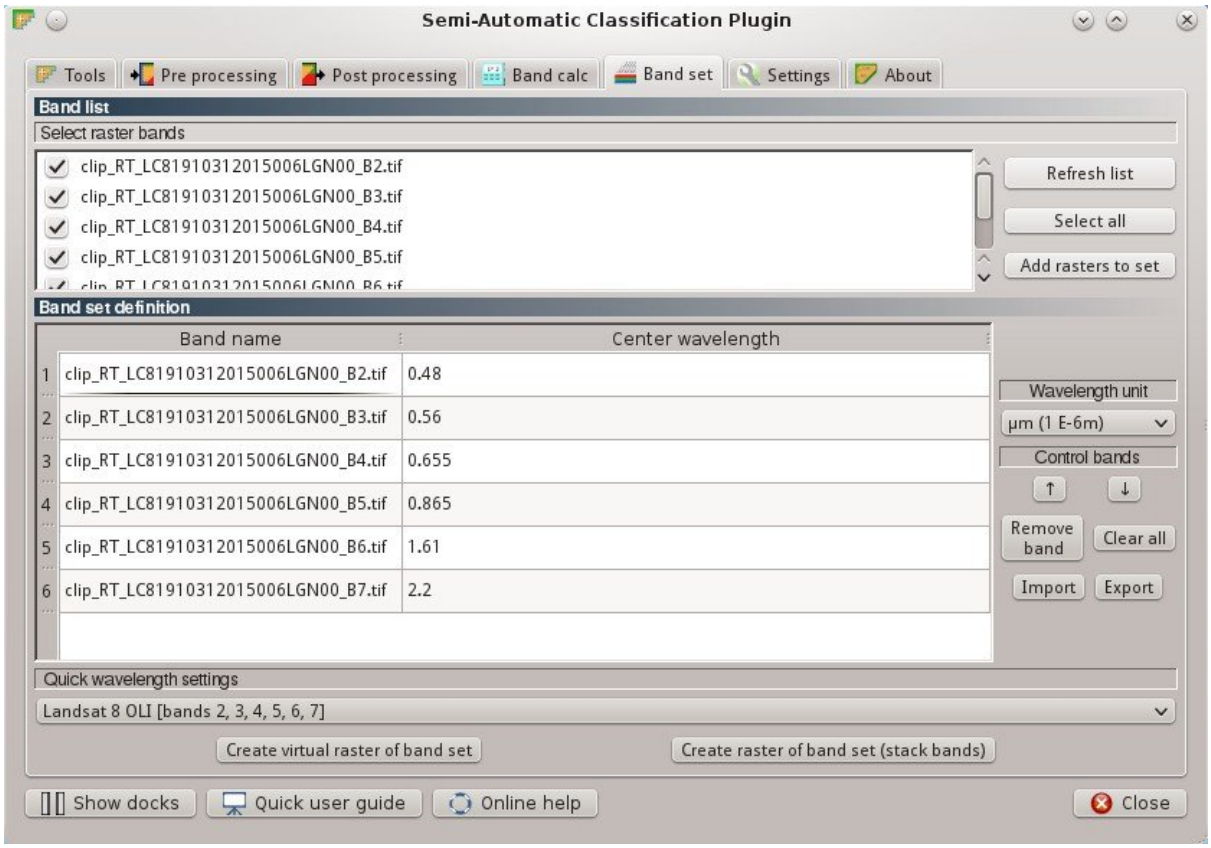


Fig. 11.11: *Definition of a band set*

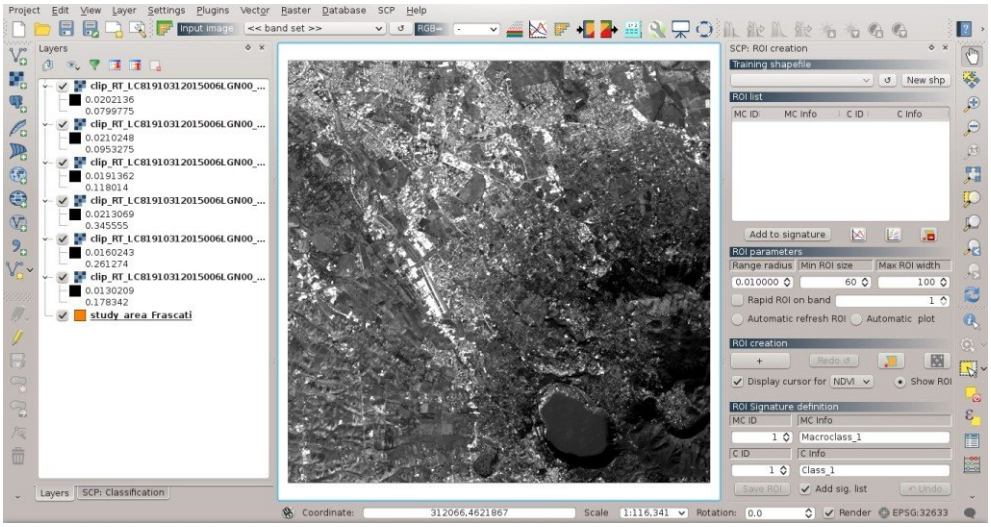
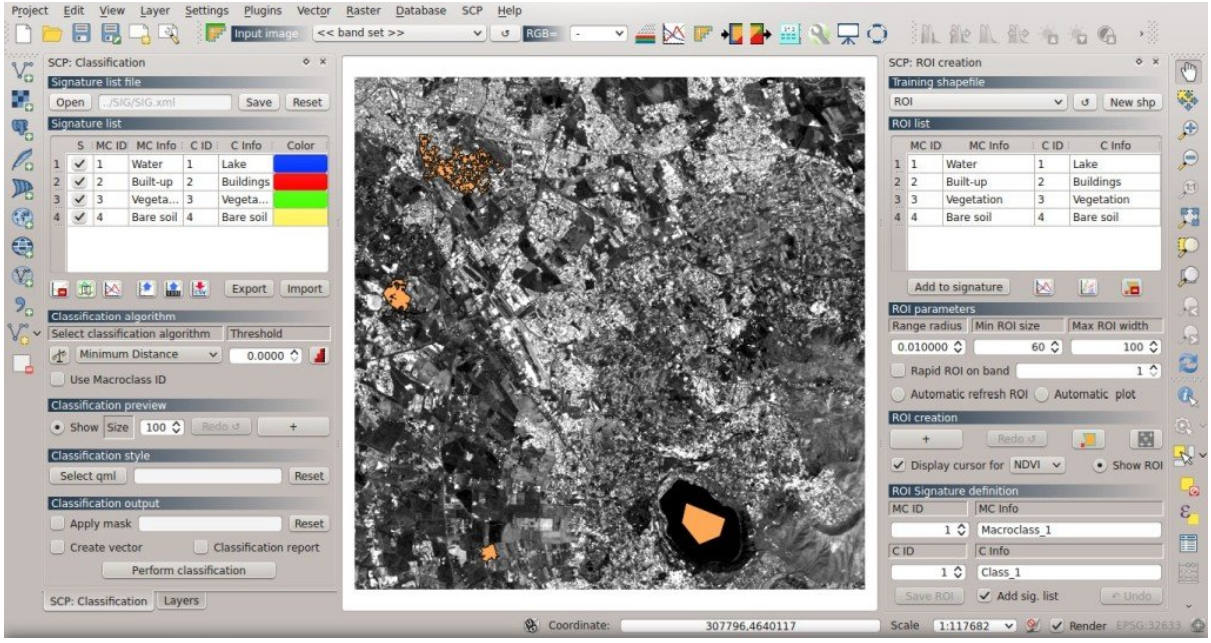


Fig. 11.12: *Band set defined*

The name of the `Training shapefile` is displayed in *Training shapefile* (page 89) of the *ROI Creation dock* (page 89) and ROIs are listed in the *ROI list* (page 91).

Also, click the button `Open` in the *Classification dock* (page 95) and select the `Signature list file` previously created (e.g. `SIG.xml`) . The path of the `Signature list file` is displayed in *Signature list file* (page 95) and the spectral signatures are loaded in the *Signature list* (page 95).



11.6 Create the ROIs

We are going to create several ROIs using the Macroclass ID defined in the following table.

Macroclass name	Macroclass ID
Water	1
Built-up	2
Vegetation	3
Bare soil	4

In the *Toolbar* (page 87) select the item `3-2-1` (which is natural color) in the list `RGB=`. After a few seconds, the *Color Composite* (page 35) will be displayed. We can see that urban areas are white and vegetation is green.

> **TIP** : If a *Band set* (page 127) is defined, a temporary virtual raster (named `band_set.vrt`) is created automatically, which allows for the display of *Color Composite* (page 35). In order to speed up the visualization, you can show only the virtual raster and hide all the single band rasters from the QGIS Layers.

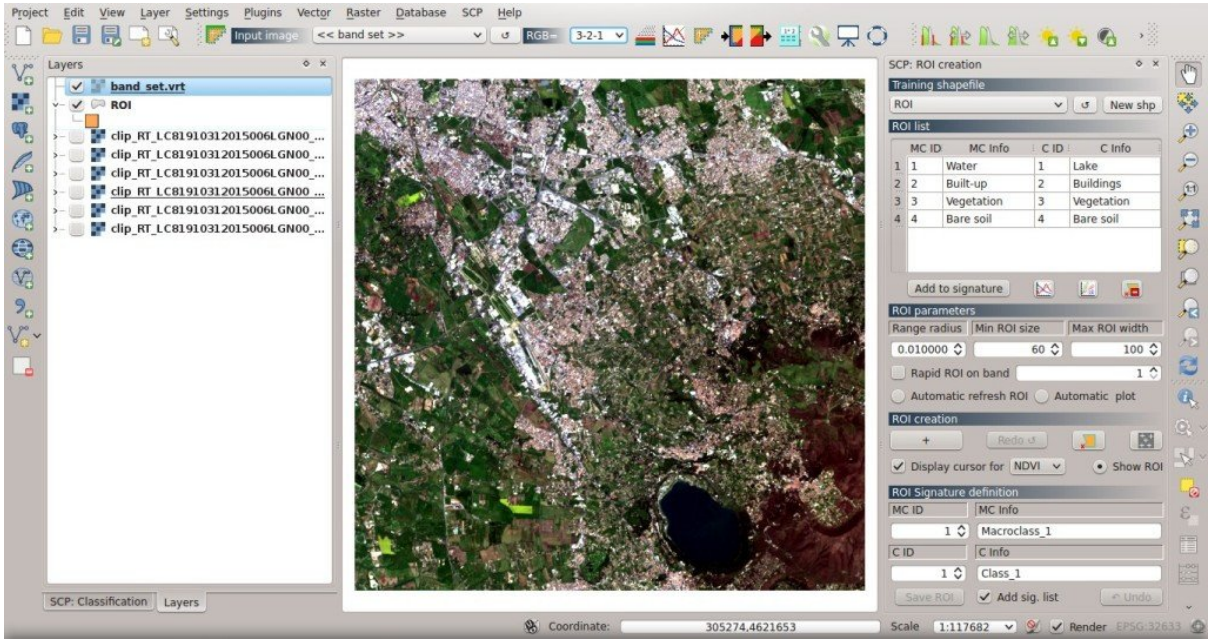


Fig. 11.13: *Color composite RGB = 3-2-1*

In the *Toolbar* (page 87) type `3-4-6` in the list `RGB=`. Using this color composite, urban areas are purple and vegetation is green. You can notice that this color composite `RGB = 3-4-6` highlights roads more than `RGB = 3-2-1`.

See *Create the ROIs* (page 58) for the details about the ROI creation by manually drawing a polygon or with an automatic region growing algorithm.

> **TIP** : Install the OpenLayers Plugin in QGIS, and add a map (e.g. OpenStreetMap) in order to facilitate the identification of ROIs using high resolution data.

After clicking the button + in the *ROI creation* (page 92) you should notice that the cursor in the map displays a value changing over the image. This is due to the function `Display cursor for NDVI` in the *ROI creation* (page 92), which displays the NDVI value of the pixel beneath the cursor. The NDVI value can be useful for identifying pure pixels, in fact vegetation has higher NDVI values than soil.

For instance, move the mouse over a vegetation area and left click to create a ROI when you see a local maximum value. This way, the created ROI and the spectral signature thereof will be particularly representative of healthy vegetation.

Create several ROIs (the more is the better). In general, you should create one ROI for each color that you can distinguish in the image. Therefore, change the color composite in order to identify the different types of land cover.

> **TIP** : Change frequently the *Color Composite* (page 35) in order to clearly identify the materials at the ground; use the mouse wheel on the list `RGB=` for changing the color composite rapidly.

A few examples of ROIs are illustrated in the following figures.

It is worth mentioning that you can show or hide the temporary ROI by switching `Show ROI` in *ROI creation* (page 92).

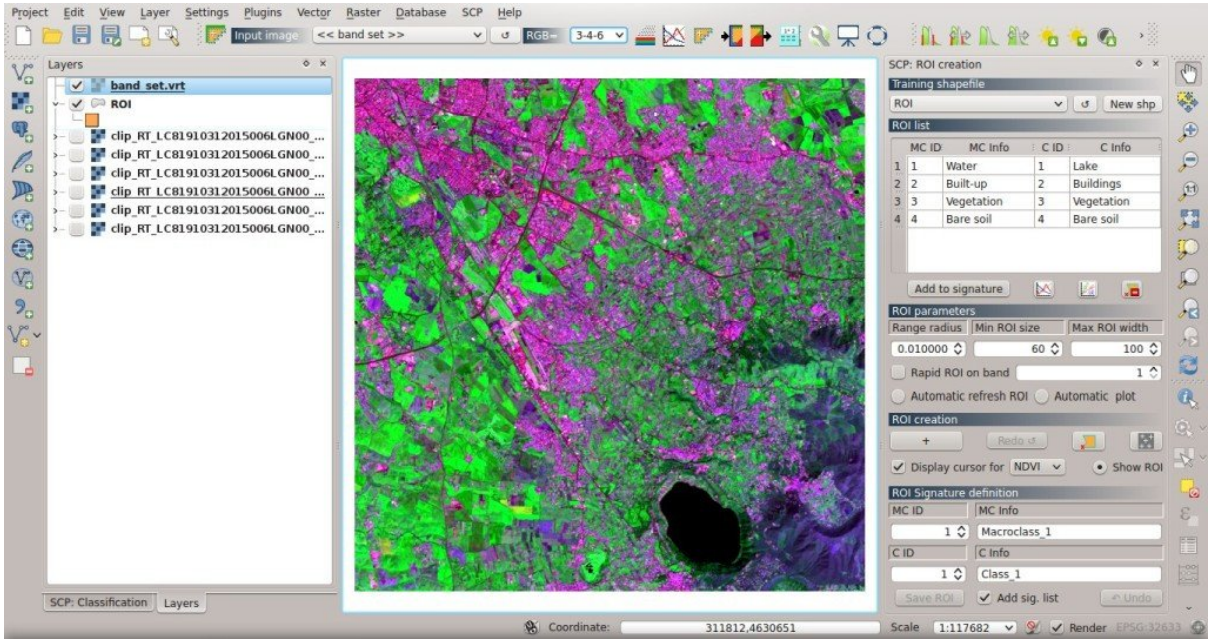


Fig. 11.14: *Color composite RGB = 3-4-6*

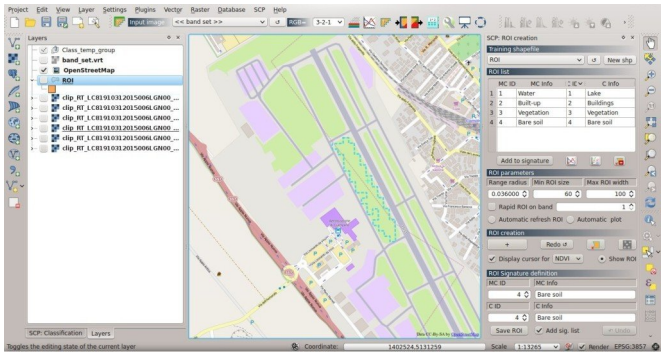


Fig. 11.15: *Creation of a ROI displaying OpenStreetMap*

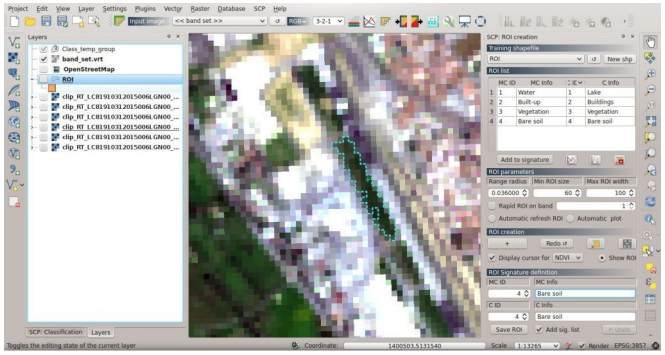


Fig. 11.16: *The same ROI displaying the color composite RGB = 3-2-1*

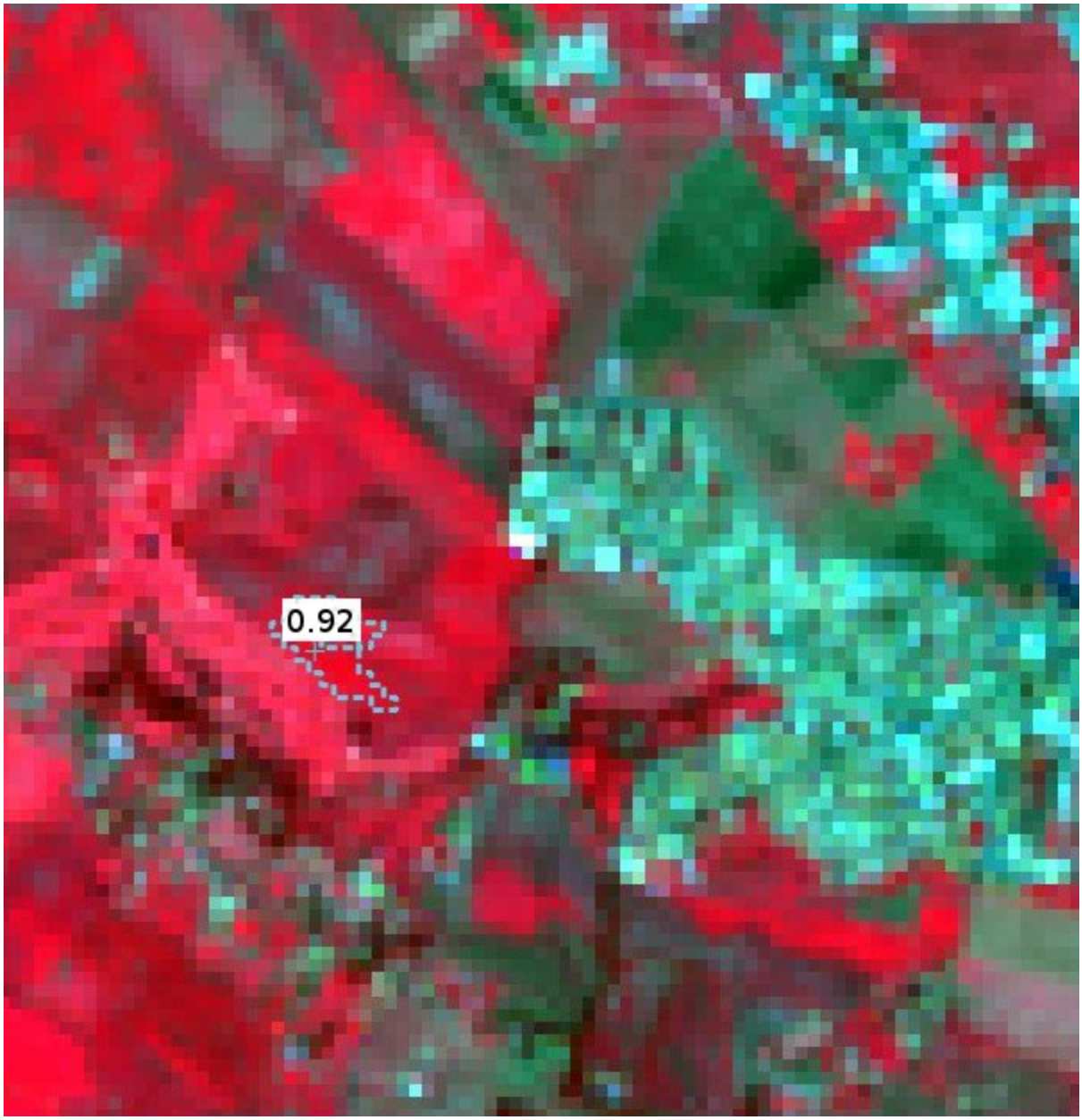


Fig. 11.17: *Example of NDVI value of vegetation displayed in the map*

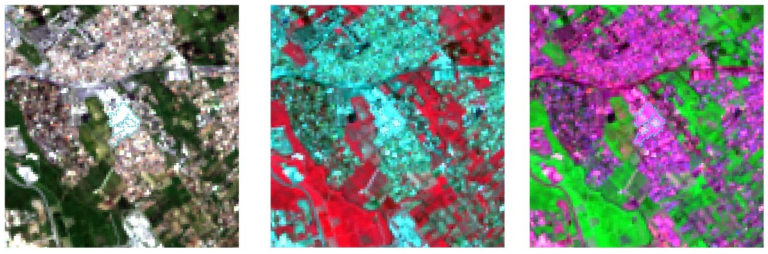


Fig. 11.18: *Built-up ROI: large buildings*

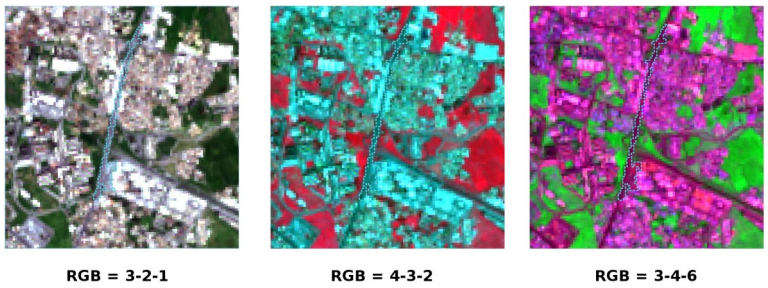


Fig. 11.19: *Built-up ROI: road*

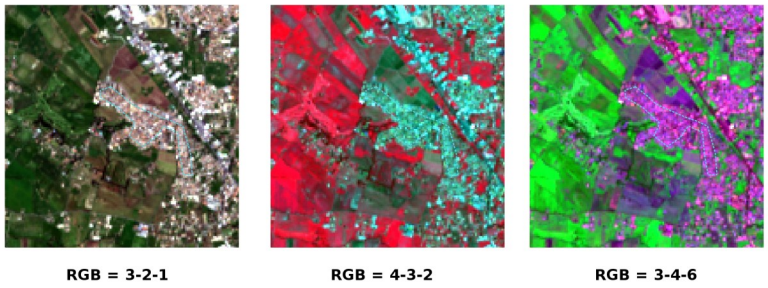


Fig. 11.20: *Built-up ROI: buildings and narrow roads*

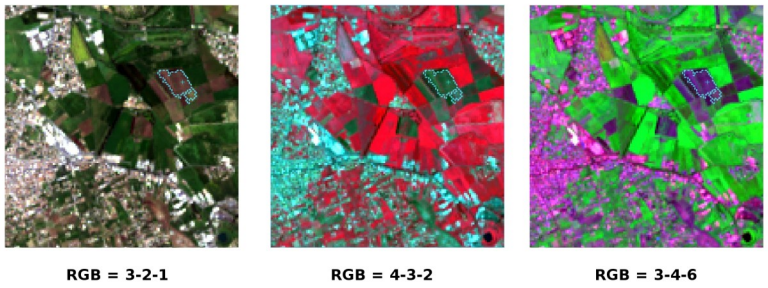


Fig. 11.21: *Bare soil ROI: uncultivated land*

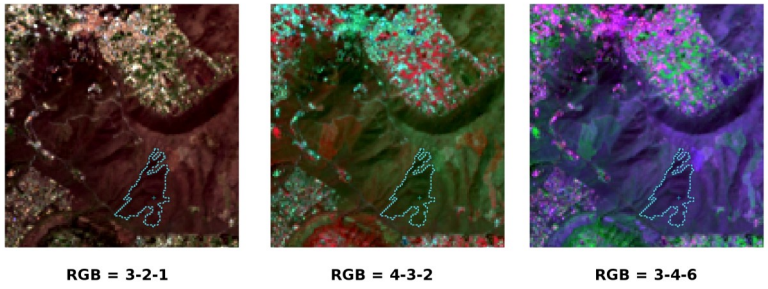


Fig. 11.22: *Vegetation ROI: deciduous trees*

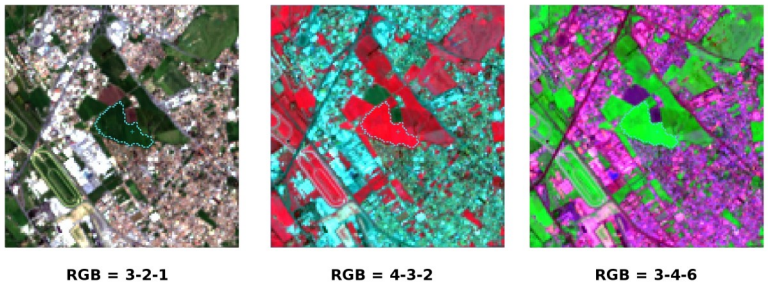


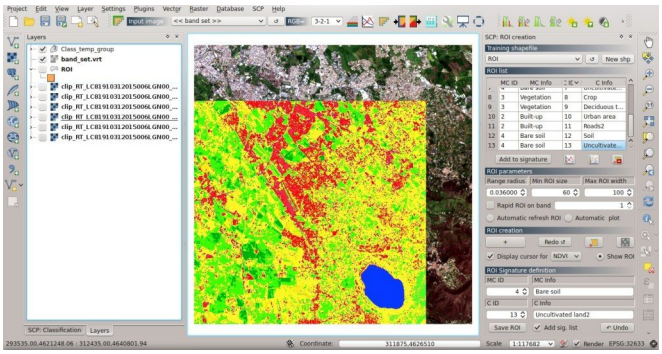
Fig. 11.23: *Vegetation ROI: crop*

11.7 Create a Classification Preview

As pointed out in *Tutorial 1: Your First Land Cover Classification* (page 57), previews are temporary classifications that are useful for assessing the effects of spectral signatures during the ROI collection.

Set the colors of the spectral signatures in the *Signature list* (page 95); then, in the *Classification algorithm* (page 97) select the classification algorithm `Spectral Angle Mapping`. In *Classification preview* (page 98) set `Size` = 500 , click the button + and then left click the map in order to create a classification preview.

The preview result is displayed in the map. Previews are temporary rasters (deleted after QGIS is closed) placed in a group named `Class_temp_group` in the QGIS panel Layers.



Place the `Class_temp_group` to the top of layers in order to display the preview over the image. Also, in *Classification preview* (page 98) switch the button `Show` in order to show or hide the previews.

In QGIS, you could notice one or more warnings similar to this `Warning [9]: The following signature has wavelength different from band set. Macro: 1 ID: 1` (see the following Figure *Warning [9]* (page 79)). This is because in *Open the Training Shapefile and Signature List File* (page 71) we have loaded the `Signature list file`, created in *Tutorial 1: Your First Land Cover Classification* (page 57) without defining the center wavelength of each band.

We need to delete the signatures created in *Tutorial 1: Your First Land Cover Classification* (page 57) from the *Signature list file* (page 95): highlight (with mouse selection in the table) these signatures and click the button . Then highlight (with mouse selection in the table) the corresponding ROIs in the *ROI list* (page 91) and click the button `Add to signature`. The spectral signatures will be calculated with the correct center wavelength and added to the *Signature list file* (page 95).

11.8 Assess Spectral Signatures

The classification algorithm uses spectral signatures for classifying the image. In general, one should use spectral signatures that are not similar, in order to avoid classification errors. Therefore, it is useful to assess signatures in

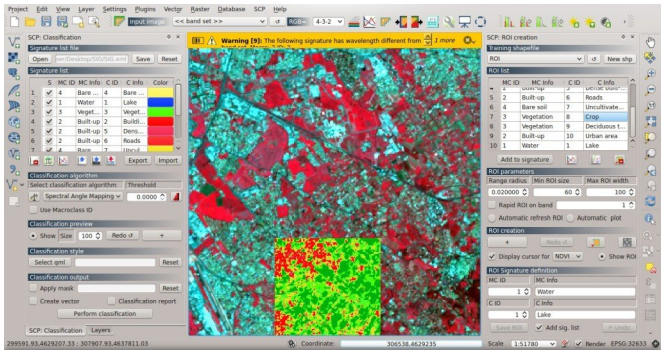
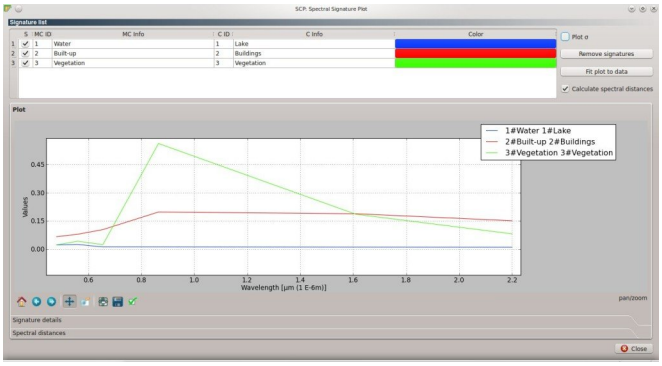


Fig. 11.24: *Warning [9]*

order to find similar spectral signatures and delete them.

Highlight (with mouse selection in the table) two or more spectral signatures in the *Signature list* (page 95) then click the button . The *Spectral Signature Plot* (page 135) is displayed in a new window. In this window you can see the spectral *Plot* (page 136) of signatures, the *Signature details* (page 138), and assess *Spectral distances* (page 138). Move inside the *Plot* (page 136) and see if signatures are similar (i.e. very close) or dissimilar (i.e. not very close).



11.9 Create the Classification Output

Repeat iteratively the phases *Create the ROIs* (page 73) and *Create a Classification Preview* (page 78) until the classification previews are good.

In order to create a classification output using only the Macroclass ID defined in *Create the ROIs* (page 73) activate the checkbox `Use Macroclass ID` in *Classification algorithm* (page 97).

In order to classify the entire image, in the *Classification output* (page 99) click the button `Perform classification` and define the name of the classification output.

You can notice that the resulting classification is better than the one created in *Tutorial 1: Your First Land Cover Classification* (page 57). However, there are other tools and techniques that can improve the results which are described in *Other Tutorials* (page 81).

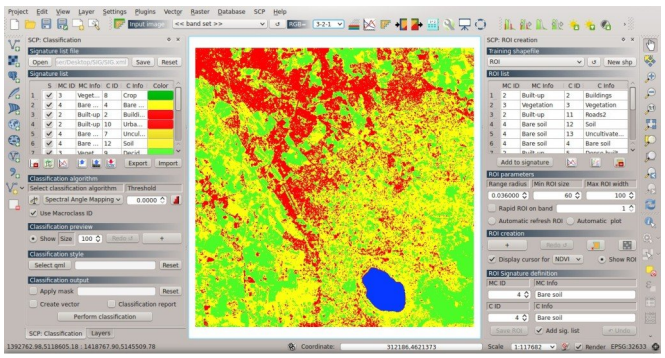


Fig. 11.25: *Resulting classification*

CHAPTER 12

Other Tutorials

Other *Thematic Tutorials* (page 147) are available about SCP functions.

Also, visit the blog From GIS to Remote Sensing for other tutorials such as:

- Supervised Classification of Hyperspectral Data;
- Monitoring Deforestation;
- Flood Monitoring;
- Estimation of Land Surface Temperature with Landsat Thermal Infrared Band;
- Land Cover Classification of Cropland.

For other unofficial tutorials, also in languages other than English, see *Where can I find more tutorials about SCP, also in languages other than English?* (page 211).

Part IV

The Interface of SCP

CHAPTER 13

SCP menu

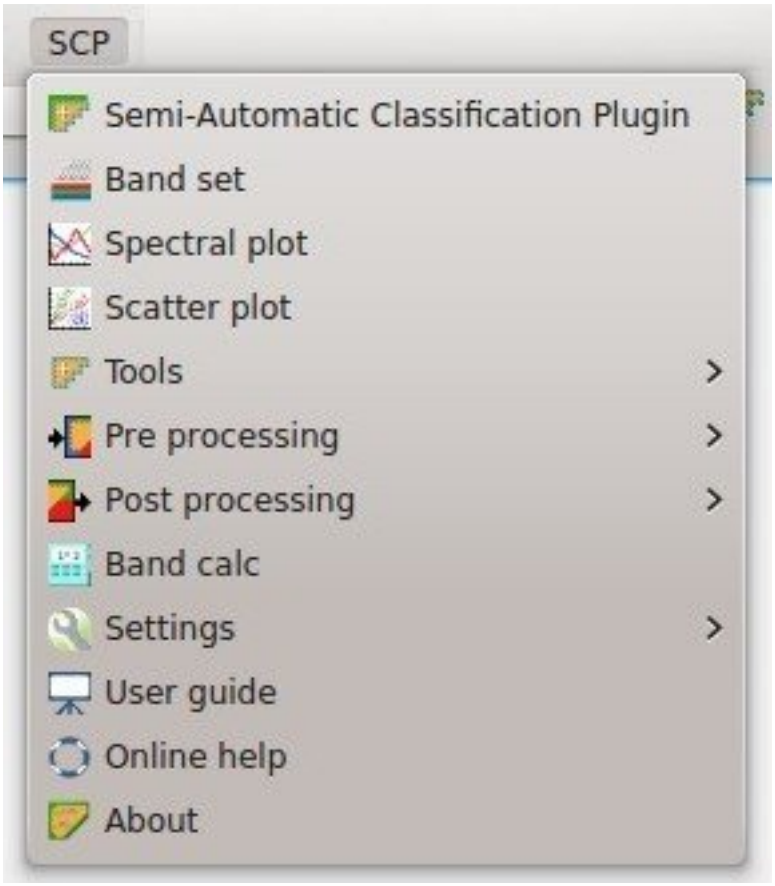


Fig. 13.1: *SCP menu*

The `SCP menu` allows for the selection of the main functions of the *Main Interface Window* (page 101), the *Spectral Signature Plot* (page 135), and the *Scatter Plot* (page 141).

- : show the *Main Interface Window* (page 101) and display the *ROI Creation dock* (page 89) and the *Classification dock* (page 95);
- : open the *Band set* (page 127);
- : open the *Spectral Signature Plot* (page 135);
- : open the *Scatter Plot* (page 141);

- : open the *Tools* (page 102) and the sub-menu thereof;
- : open the *Pre processing* (page 114) and the sub-menu thereof;
- : open the *Post processing* (page 117) and the sub-menu thereof;
- : open the *Band calc* (page 125);
- : open the *Settings* (page 129) and the sub-menu thereof;
- : open the online user manual in a web browser;
- : open the Online help in a web browser; also, a Facebook group and a Google+ Community are available for sharing information and asking for help about SCP.

CHAPTER 14

Toolbar

Fig. 14.1: *Toolbar*

The `Toolbar` allows for the selection of the `Input image`, and includes several buttons for opening the main functions of the *Main Interface Window* (page 101).

The following video shows this tool.

http://www.youtube.com/watch?t=140&v=nZffzX_sMnk

Alternative video link https://archive.org/details/video_basic_tutorial_1?start=140

[P] = Configuration stored in the active project of QGIS

[Q] = Configuration stored in QGIS registry

- : show the *Main Interface Window* (page 101) and display the *ROI Creation dock* (page 89) and the *Classification dock* (page 95);
- : open the *Band set* (page 127);
- `Input image` [P]: select the input image from a list of multi-spectral images loaded in QGIS; input image can be a multi-spectral raster or a set of single bands defined in the *Band set* (page 127) (if the *Band set* (page 127) is defined, then this list will contain the item << *band set* >>;
- : refresh image list;
- `RGB=` [P]: select a color composites that is applied to the `Input image` ; new color composites can be defined typing the band numbers separated by `-` or `;` or `,` (e.g. RGB = 4-3-2 or RGB = 4;3;2 or RGB = 4,3,2);
- < `Show` >: show/hide the input image in the map;
- : display the input image stretching the minimum and maximum values according to cumulative count of current extent;
- : display the input image stretching the minimum and maximum values according to standard deviation of current extent;
- : open the *Spectral Signature Plot* (page 135);
- : open the *Tools* (page 102);

- : open the *Pre processing* (page 114);
- : open the *Post processing* (page 117);
- : open the *Band calc* (page 125);
- : open the *Settings* (page 129);
- : open the online user manual in a web browser;
- : open the Online help in a web browser; also, a Facebook group and a Google+ Community are available for sharing information and asking for help about SCP.

CHAPTER 15

ROI Creation dock

The dock `ROI creation` allows for the definition of a **training shapefile**, and for the creation of **ROIs** (Regions Of Interest) using a **region growing** algorithm or **manual drawing**.

The training shapefile, created with SCP, is used for storing the ROI polygons.

SCP allows for the creation of **temporary ROI polygons** using a region growing algorithm (i.e. image is segmented around a pixel seed including spectrally homogeneous pixels). Alternatively, ROIs can be drawn manually. Temporary ROIs are displayed over the image. If the ROI characteristics (e.g. spectral signature) are considered acceptable, then it can be saved in the training shapefile and the spectral characteristics are saved in the *Signature list file* (page 95).

It is worth pointing out that classification is not based on ROIs, but it is based on the spectral characteristics of signatures in the *Signature list* (page 95) .

ROIs are defined with a **Macroclass ID and Class ID** (see *Classes and Macroclasses* (page 39)) that are used for the classification process; in addition, Macroclass Information (e.g. macroclass name) and Class Information (e.g. class name) can be defined, but they are not used in the classification process.

Training shapefiles (which can be created by SCP) must contain at least four fields as in the following table (custom names can be defined in the *Field names of training shapefile* (page 129)).

Description	Field name	Field type
Macroclass ID	MC_ID	int
Macroclass Information	MC_info	string
Class ID	C_ID	int
Class Information	C_info	string

The following video shows this tool.

http://www.youtube.com/watch?t=230&v=nZffzX_sMnk

Alternative video link https://archive.org/details/video_basic_tutorial_1?start=230

[P] = Configuration stored in the active project of QGIS

[Q] = Configuration stored in QGIS registry

15.1 Training shapefile

- `Training shapefile` [P]: select a shapefile from a list of shapefiles (containing the required fields) loaded in QGIS; ; ROIs polygons are saved in this shapefile;
- : refresh layer list;
- [`New shp`]: create a new shapefile containing the required fields Macroclass ID, Macroclass Information , Class ID, and Class Information.

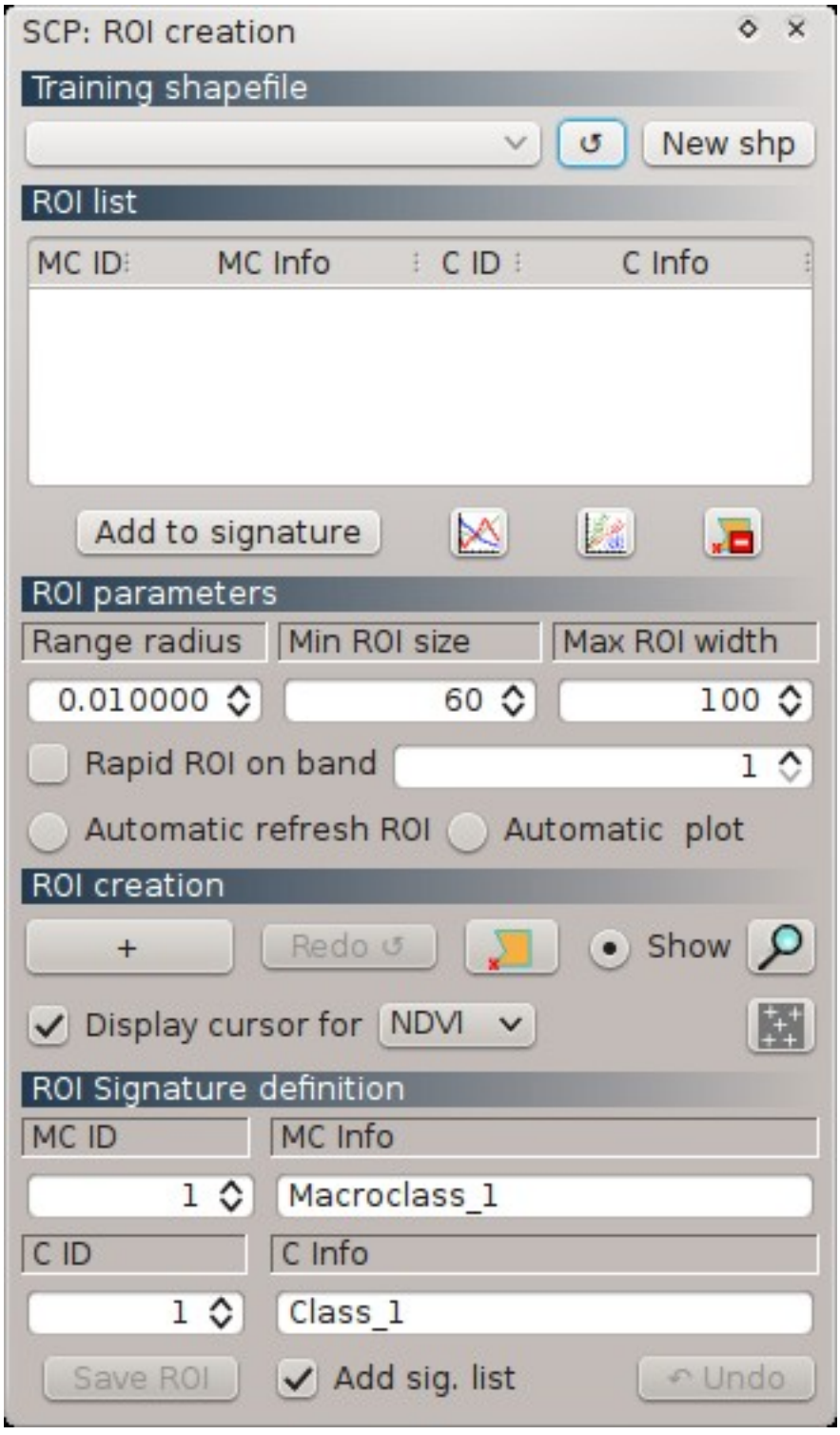


Fig. 15.1: *ROI creation dock*

Fig. 15.2: *Training shapefile*

WARNING: In order to avoid data loss, do not edit the `Training shapefile` in QGIS while it is loaded in the *Training shapefile* (page 89).

15.2 ROI list

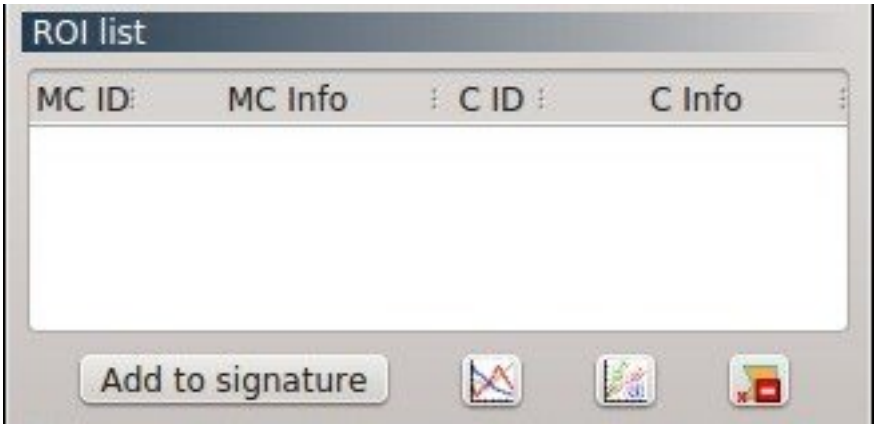


Fig. 15.3: *ROI list*

The `ROI list` displays the ROI polygons collected in the `Training shapefile`. Double click on any table item to zoom in the map to that ROI; also, ROIs can be edited within this table (changes affect also the shapefile). In order to highlight items perform a mouse selection in the table.

- **Table fields:**
  - `MC ID` : ROI Macroclass ID [int];
  - `MC Info` : ROI Macroclass Information [text];
  - `C ID` : ROI Class ID [int];
  - `C Info` : ROI Class Information [text];
- [`Add to signature`]: calculate ROI spectral signature (from `Input image` pixels under ROI polygon) of highlighted ROIs in the table; signatures are added to the *Signature list* (page 95); if multiple highlighted ROIs share the same `MC ID` and `C_ID`, then only one spectral signature is calculated considering these ROIs as one polygon;
- : show the ROI spectral signature the *Spectral Signature Plot* (page 135); spectral signature is calculated from the `Input image`;
- : open the *Scatter Plot* (page 141);
- : delete highlighted ROIs from the `Training shapefile`.

15.3 ROI parameters

ROI parameters are required for the ROI creation using a region growing algorithm. Region growing works on the `Input image` defined in the *Toolbar* (page 87).

- `Range radius` [P]: set the interval which defines the maximum spectral distance between the seed pixel and the surrounding pixels (in radiometry unit);
- `Min ROI size` [P]: set the minimum area of a ROI (in pixel unit); this setting overrides the `Range radius` until the minimum ROI size is reached; if `Rapid ROI on band` is checked, then ROI will

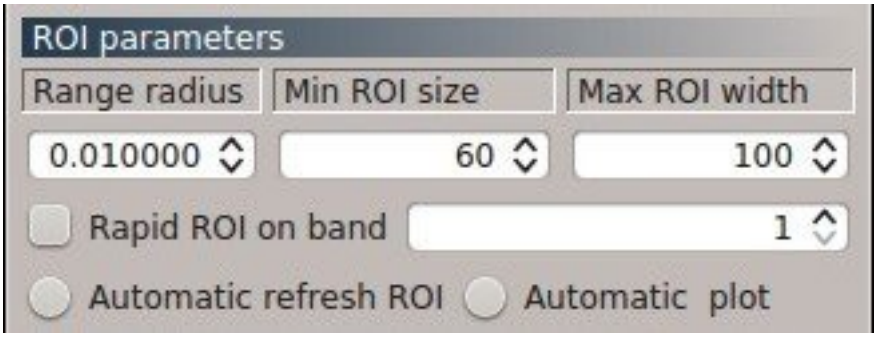


Fig. 15.4: *ROI parameters*

have at least the size defined `Min ROI size`; if `Rapid ROI on band` is unchecked, then ROI could have a size smaller than `Min ROI size`;

- `Max ROI width` [P]: set the maximum width of a ROI (i.e. the side length of a square, centred at the seed pixel, which inscribes the ROI) in pixel unit;
- `Rapid ROI on band` [P]: if checked, ROI is created using only the selected band of the `Input image` defined in the combo box (the process is quicker); if unchecked, ROI is the result of the intersection between ROIs calculated using every band (the process is longer, but ROI is spectrally homogeneous on every band);
- `Automatic refresh ROI` : create automatically a new ROI while `Range radius` , `Min ROI size` , or `Max ROI width` are changed;
- `Automatic plot` : calculate automatically the ROI spectral signature and display it in the *Spectral Signature Plot* (page 135) (spectral signature has `MC Info = tempo_ROI`).

15.4 ROI creation

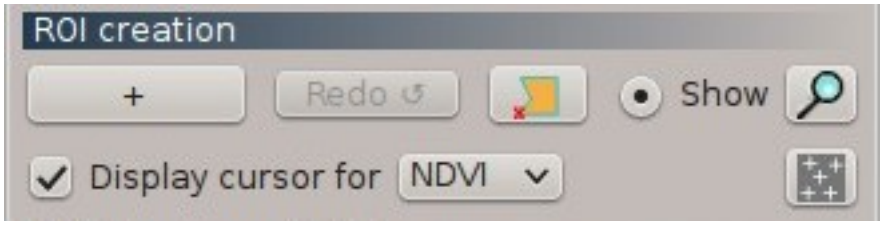


Fig. 15.5: *ROI creation*

ROI creation is used for creating ROI polygons; these ROIs are **temporary** until they are saved in the *Training shapefile* (page 89) .

- [+]: recall the pointer for ROI creation using the region growing algorithm; **left click** on the map for creating the ROI: **right click** on the map for displaying the spectral signature of a pixel of the `Input image`;
- [`Redo`]: create a new ROI using the region growing algorithm at the same point of the previous one;
- : create a ROI by manual drawing a polygon on the map; after clicking the button, left click on the map to define the ROI vertices and right click to define the last vertex closing the polygon;
- : open the *Multiple ROI Creation* (page 102);
- < `Display cursor for` > [P]: if the ROI creation pointer is active, display vegetation index values on the map; vegetation indices available in the combo box are NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index); NDVI requires the near-infrared and red bands; EVI requires

the blue, near-infrared and red bands converted to reflectance; wavelengths must be defined in the *Band set* (page 127);

- < `Show` >: show/hide the temporary ROI in the map;
- : zoom to the last temporary ROI.

15.5 ROI Signature definition

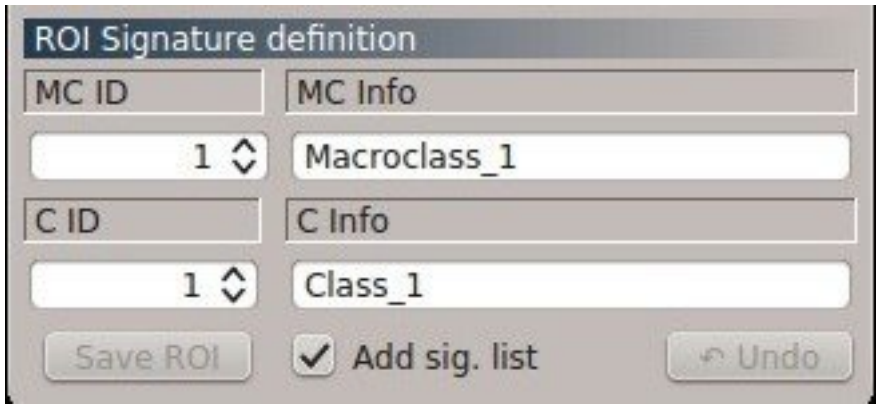


Fig. 15.6: *ROI Signature definition*

This allows for the definition of ROI's class and saving the temporary ROI to the *Training shapefile* (page 89) ; in addition, it is possible to automatically calculate the ROI spectral signature and add it to the *Signature list* (page 95) .

- `MC ID` [P]: ROI Macroclass ID [int];
- `MC Info` [P]: ROI Macroclass information [text];
- `C ID` [P]: ROI Class ID [int];
- `C Info` [P]: ROI Class information [text];
- [`Save ROI`]: save the temporary ROI to the *Training shapefile* (page 89) ;
- `Add sig. list` [P]: if checked, the spectral signature is calculated (the ROI mean value, and standard deviation for each raster band, and the covariance matrix) while the ROI is saved to shapefile (it takes some time depending on the number of `Input image` bands);
- [`Undo`]: delete the last saved ROI from the *Training shapefile* (page 89) .

CHAPTER 16

Classification dock

The dock `Classification` is designed to manage the **spectral signatures**, and **classify** the `Input image`.

Spectral signatures define the characteristics of land cover classes. Only spectral signatures in the *Signature list* (page 95) are used by classification algorithms. Spectral signatures are calculated from the ROIs of a `Training shapefile` (defined in the *ROI Creation dock* (page 89)). In addition, spectral signatures can be imported from files, from ASTER spectral libraries, or from the *USGS Spectral Library* (page 104).

Spectral signatures are saved in **signature list file** (.xml).

The use of the `Macroclass ID` or `Class ID` for classifications is defined with the option `Use Macroclass ID` in the *Classification algorithm* (page 97).

The **classification** can be performed for the entire image (*Classification output* (page 99)) or a part of it, creating a *Classification preview* (page 98).

The following video shows this tool.

http://www.youtube.com/watch?t=718&v=nZffzX_sMnk

Alternative video link https://archive.org/details/video_basic_tutorial_1?start=718

[P] = Configuration stored in the active project of QGIS

[Q] = Configuration stored in QGIS registry

16.1 Signature list file

- `Open` [P]: open a signature list file (a .xml file) loading the signatures in the *Signature list* (page 95) and displaying the file path (absolute or relative path according to QGIS project settings);
- `Save` : save the signature list to the open file; if no signature list is open, a window will ask for the creation of a new signature file;
- `Reset` : clear the path of the signature list file.

16.2 Signature list

The `Signature list` displays loaded spectral signatures. Spectral signatures are automatically saved in the *Signature list file* (page 95) every time the QGIS project is saved, or when the button `Save` is clicked. In order to highlight items perform a mouse selection in the table.

- **Table fields:**
  - `S` : checkbox field; only the spectral signatures checked in this list are used for the classification process; double click on any item to check/uncheck all the items in the list;
  - `MC ID` : signature Macroclass ID [int]; it can be edited with a single click;

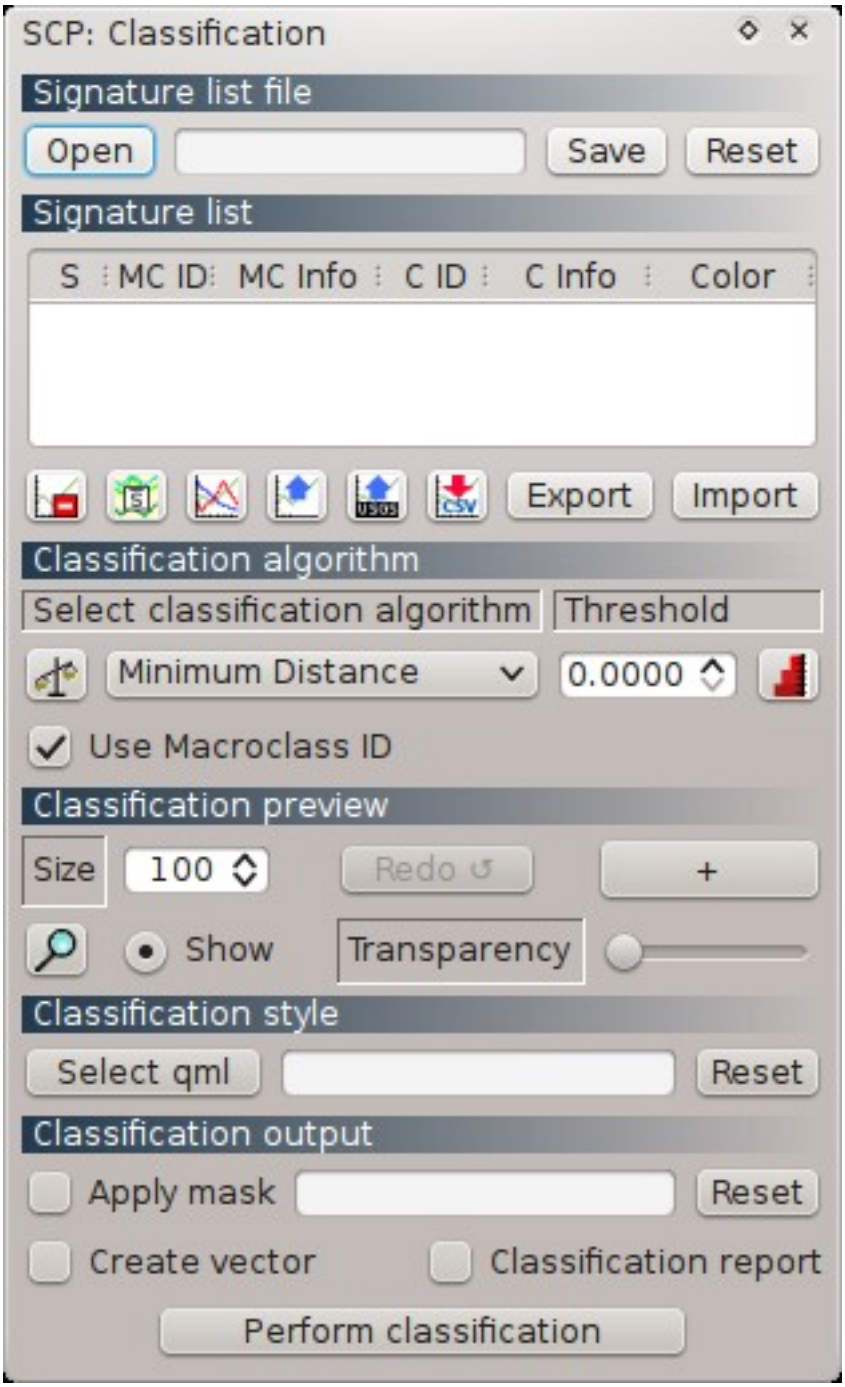


Fig. 16.1: *Classification dock*

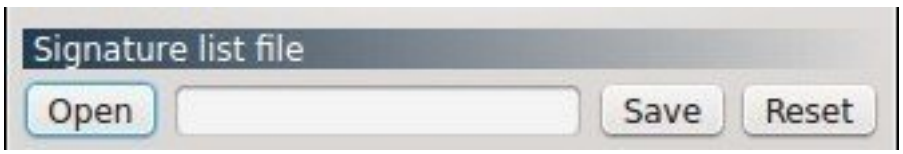


Fig. 16.2: *Signature list file*

Fig. 16.3: *Signature list*

  - `MC Info` : signature Macroclass Information [text]; it can be edited with a single click;
  - `C ID` : signature Class ID [int]; it can be edited with a single click;
  - `C Info` : signature Class Information [text]; it can be edited with a single click;
  - `Color` : color field; double click to select a color for the class that is used in the classification.

- : delete highlighted spectral signatures from the list;
- : merge highlighted spectral signatures obtaining a new signature calculated as the average of signature values for each band (covariance matrix is excluded);
- : add highlighted signatures to the *Spectral Signature Plot* (page 135);
- : import a spectral library from ASTER spectral libraries (i.e. files .txt downloaded from http://speclib.jpl.nasa.gov), USGS spectral libraries (i.e. files .asc downloaded from http://speclab.cr.usgs.gov/spectral-lib.html), or generic .csv files;
- : open the *USGS Spectral Library* (page 104) for importing USGS spectral libraries directly from internet;
- : open a window for exporting signatures; every signature is exported as a .csv file in the selected directory;
- `Export`: export the signature list to a new signature file (i.e. a .xml file for the *Signature list file* (page 95));
- `Import`: import a .xml file, adding the spectral signatures to the ones already loeaded in the `Signature list`.

16.3 Classification algorithm

- : open the *Algorithm band weight* (page 106) for the definition of band weights;
- **`Select a classification algorithm`** [select one of the *Classification Algorithms* (page 40); available classification algorithms are:]
  - *Minimum Distance* (page 40);
  - *Maximum Likelihood* (page 41);
  - *Spectra Angle Mapping* (page 42);

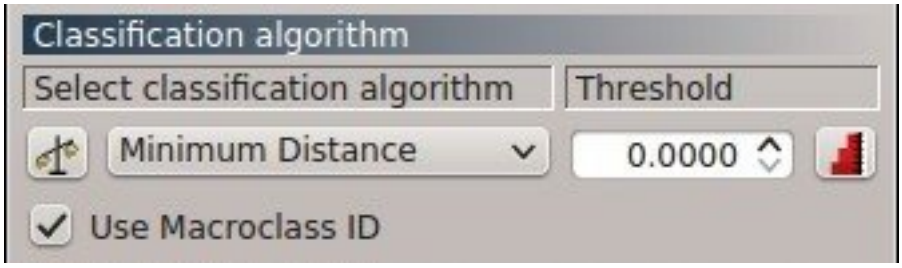


Fig. 16.4: *Classification algorithm*

- **`Threshold` [optional]: allows for the definition of a classification threshold for all the spectral signatures (for individ**
  - for Minimum Distance, pixels are unclassified if distance is greater than threshold value;
  - for Maximum Likelihood, pixels are unclassified if probability is less than threshold value (max 100);
  - for Spectral Angle Mapping, pixels are unclassified if spectral angle distance is greater than threshold value (max 90);
- `Use Macroclass ID` : if checked, the classification is performed using the Macroclass ID (code *MC ID* of the signature); if unchecked, then the classification is performed using the Class ID (code *C ID* of the signature);
- : open the *Signature threshold* (page 107) for the definition of signature thresholds.

16.4 Classification preview

Fig. 16.5: *Classification preview*

Classification previews are temporary classifications of part of the *input image* (every pixel has a value that represents a class). Also, a algorithm raster can be displayed with a click on the map; algorithm raster represents the distance of the classified pixel to the corresponding signature (every pixel has a value calculated by the algorithm with the spectral signature); algorithm raster is useful for assessing how much a pixel classified as class *X* is distant from the corresponding spectral signature *X* (black pixels are distant from the spectral signature and white pixels are closer). After the creation of a new preview, old previews are placed in QGIS Layers inside a layer group named `Class_temp_group` (custom name can be defined in *Temporary group name* (page 131)) and are deleted when the QGIS session is closed.

- < `Size` >: size in pixel unit of a classification preview (i.e. the side length of a square, centred at the clicked pixel);
- [`Redo`]: create a new classification preview centred at the same pixel of the previous one;
- [+]: activate the pointer for the creation of a classification preview ; left click the map for starting the classification process and showing the classification preview; right click for starting the classification process and showing the algorithm raster of the preview;

- : zoom to the last temporary preview in the map;
- < `Show` >: show/hide the temporary preview in the map;
- [- `Transparency` -]: change temporary preview transparency on the fly, which is useful for comparing the results to input image.

16.5 Classification style

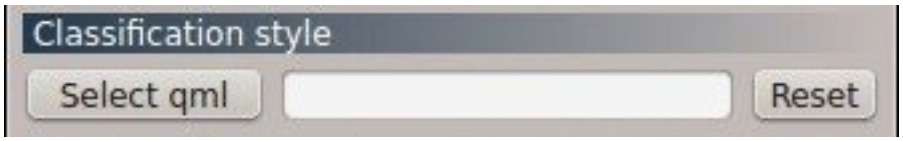


Fig. 16.6: *Classification style*

Class colors (for classifications and previews) are defined in the *Signature list* (page 95) ; in addition, a *classification style* can be loaded from a QGIS .qml file saved previously.

- [`Select qml`] [P]: select a .qml file overriding the colors defined in the *Signature list* (page 95) ;
- [`Reset`]: reset style to default (i.e. class colors are derived from the *Signature list* (page 95)).

16.6 Classification output

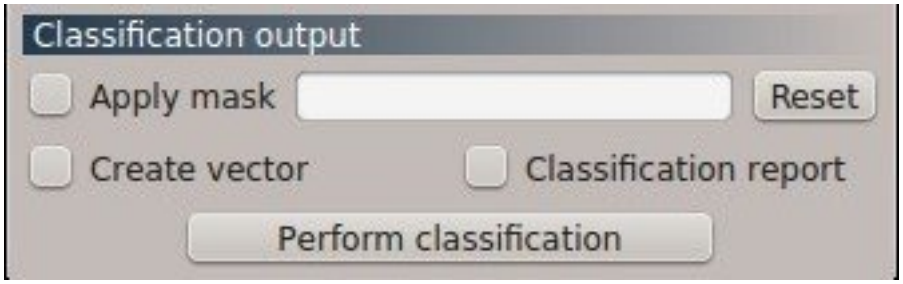


Fig. 16.7: *Classification output*

The **classification output** is a .tif raster file.

- `Apply mask` [optional]: if checked, a mask shapefile can be selected and used for masking the classification (i.e. the part of *input image* that is outside the mask shapefile will not be classified);
- [`Reset`]: reset the shapefile mask;
- `Create vector` [optional]: if checked, when `Perform classification` is clicked, a shapefile of the classification is saved inside the same folder and with the same name defined for the classification output; conversion to vector can also be performed later in *Classification to vector* (page 121);
- `Classification report` [optional]: if checked, when `Perform classification` is clicked, a report about the land cover classification is calculated providing the pixel count, the percentage and area for each class; the report is saved as a .csv file in the same folder and with the same name defined for the classification output and the suffix `_report`; in addition, the results are shown in the *Classification report* (page 121);
- [`Perform classification`]: define a classification output (a .tif file) and perform the image classification (the .qml file of the QGIS style is saved along with the classification).

CHAPTER 17

Main Interface Window

The Main Interface Window is composed of several tabs grouped in sections. Each section contains several functions that are useful for the classification process, the pre processing of images, and the post processing of land cover classifications.

Three buttons are always available:

- `Show docks` : show the *ROI Creation dock* (page 89) and the *Classification dock* (page 95) if closed;
- `Quick user guide` : open the online user manual in a web browser;
- `Online help` : open the Online help in a web browser; also, a Facebook group and a Google+ Community are available for sharing information and asking for help about SCP.

[P] = Configuration stored in the active project of QGIS

[Q] = Configuration stored in QGIS registry

Following, the list of tabs and the description thereof:

- *Tools* (page 102)
  - *Multiple ROI Creation* (page 102)
  - *USGS Spectral Library* (page 104)
  - *Algorithm band weight* (page 106)
  - *Signature threshold* (page 107)
  - *Download Landsat* (page 108)
  - *Download Sentinel* (page 112)
- *Pre processing* (page 114)
  - *Landsat* (page 114)
  - *Clip multiple rasters* (page 116)
  - *Split raster bands* (page 117)
- *Post processing* (page 117)
  - *Accuracy* (page 117)
  - *Land cover change* (page 120)
  - *Classification report* (page 121)
  - *Classification to vector* (page 121)
  - *Reclassification* (page 124)
- *Band calc* (page 125)
  - *Band list* (page 126)
  - *Expression* (page 126)
  - *Output raster* (page 127)
- *Band set* (page 127)
  - *Band list* (page 128)
  - *Band set definition* (page 128)
- *Settings* (page 129)
  - *Settings: Interface* (page 129)
  - *Settings: Processing* (page 131)
  - *Settings: Debug* (page 132)

17.1 Tools

The tab `Tools` includes several tools for the creation and manipulation of ROI and spectral signatures.

17.1.1 Multiple ROI Creation

The tab `Multiple ROI Creation` allows for the automatic creation of ROIs, useful for the rapid classification of multi-temporal images, or for accuracy assessment (see this tutorial). It performs the region growing of ROIs at user defined points, requiring a list of point coordinates and class definitions. Created ROIs are automatically saved to the *Training shapefile* (page 89).

The following video shows this tool.

http://www.youtube.com/watch?v=MxBwMQnyZKw

Point coordinates and ROI definition

- **Table fields:**
  - `X [float]` : point X coordinate;
  - `Y [float]` : point Y coordinate;
  - `MC ID` [P]: ROI Macroclass ID [int];
  - `MC Info` [P]: ROI Macroclass information [text];
  - `C ID` [P]: ROI Class ID [int];

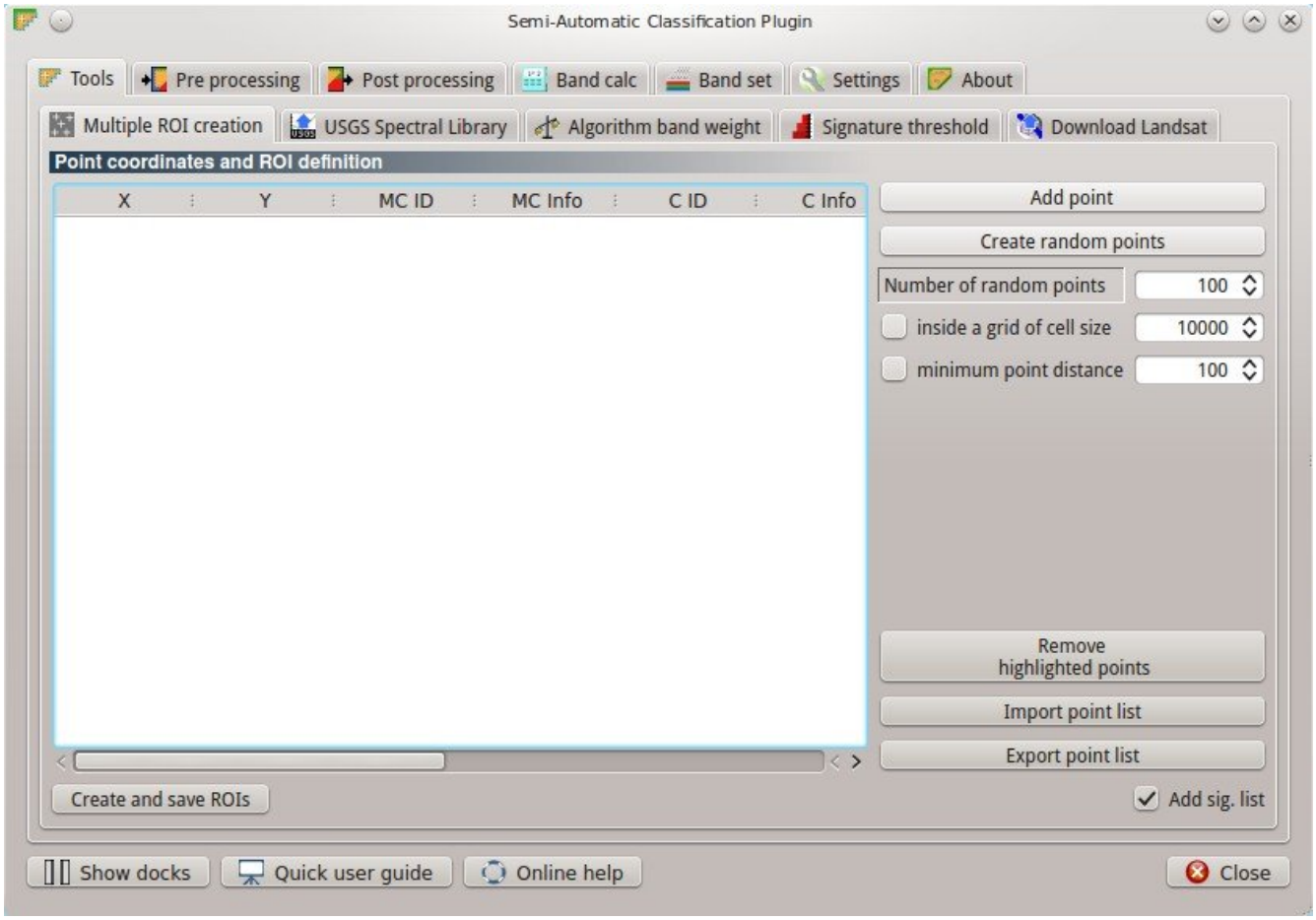


Fig. 17.1: *Multiple ROI Creation*

  - `C Info` [P]: ROI Class information [text];
  - `Min size [int]` : the minimum area of a ROI (in pixel unit) corresponding to `Min ROI size` in *ROI parameters* (page 91) ;
  - `Max width [int]` : the maximum width of a ROI corresponding to `Max ROI width` in *ROI parameters* (page 91) ;
  - `Range radius [float]` : the interval which defines the maximum spectral distance between the seed pixel and the surrounding pixels (in radiometry unit) corresponding to `Range radius` in *ROI parameters* (page 91) ;
  - `Rapid ROI band [int]` : if defined, ROI is created only on the selected band; corresponding to `Rapid ROI on band` in *ROI parameters* (page 91) ;

- [`Add point`]: add a new row to the table for the definition a point; all the table fields must be filled for the ROI creation;
- [`Create random points`]: create random points inside the `input image` area; the point amount is defined in `Number of random points`;
- [`Number of random points`]: set a number of points that will be created when `Create random points` is clicked;
- `inside a grid of cell size`: if checked, the `input image` area is divided in cells where the size thereof is defined in the combobox [image unit, usually meters]; points defined in `Number of random points` are created randomly within each cell;
- `minimum point distance`: if checked, random points have a minimum distance defined in the combobox [image unit, usually meters]; setting a minimum distance can result in fewer points than the number defined in `Number of random points`;
- [`Remove highlighted points`]: delete the highlighted rows from the table;
- [`Import point list`]: import a point list from text file to the table; every line of the text file must contain values separated by tabs of `X [float]`, `Y [float]`, `MC ID [int]`, `MC Info [text]`, `Class ID [int]`, `C Info [text]`, `Min size [int]`, `Max width [int]`, `Range radius [float]`, and optionally the `Rapid ROI band [int]`;
- [`Export point list`]: export the point list to text file;
- [`Create and save ROIs`]: start the ROI creation process for all the points and save ROIs to the Training shapefile;
- `Add sig. list`: if checked, the spectral signature is calculated (the ROI mean value, and standard deviation for each raster band, and the covariance matrix) while the ROI is saved to shapefile (it takes some time depending on the number of `Input image` bands).

17.1.2 USGS Spectral Library

The tab `USGS Spectral Library` allows for the download of the USGS spectral library (Clark, R.N., Swayze, G.A., Wise, R., Livo, E., Hoefen, T., Kokaly, R., Sutley, S.J., 2007, USGS digital spectral library splib06a: U.S. Geological Survey, Digital Data Series 231). The libraries are grouped in chapters including Minerals, Mixtures, Coatings, Volatiles, Man-Made, Plants, Vegetation Communities, Mixtures with Vegetation, and Microorganisms. The downloaded library is automatically sampled according to the image band wavelengths defined in the *Band set* (page 127), and added to the *Signature list* (page 95).

Select a chapter

- `Select a chapter` : select one of the library chapters; after the selection, chapter libraries are shown in *Select a library* (page 106);

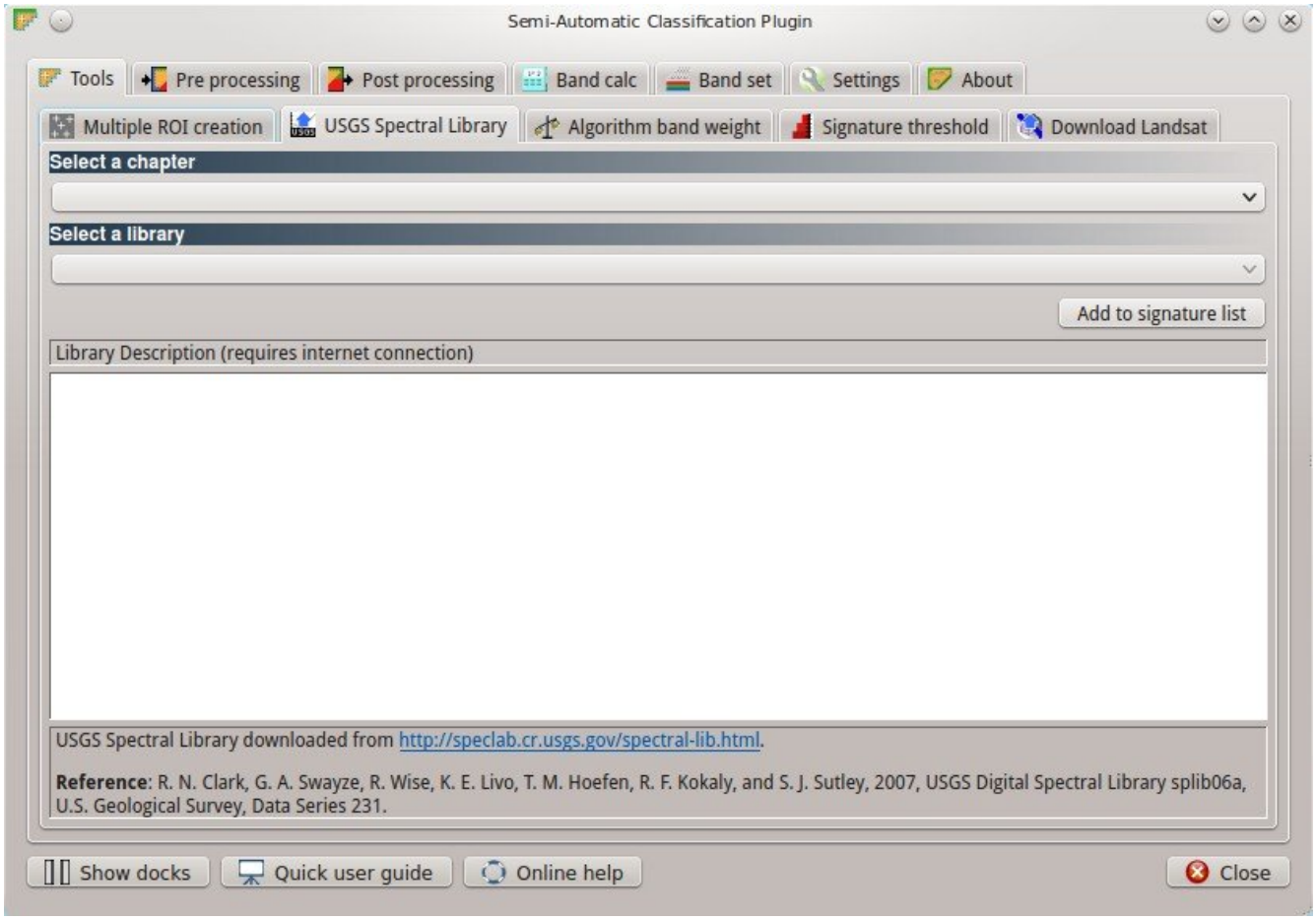


Fig. 17.2: *USGS Spectral Library*

Select a library

- `Select a library` : select one of the libraries; the library description is displayed in the frame `Library description`;
- `Add to signature list [internet connection required]` : download the library and add the sampled spectral signature to the *Signature list* (page 95) using the parameters defined in *ROI Signature definition* (page 93).

  Tip: spectral libraries downloaded from the `USGS Spectral Library` can be used with Minimum Distance or Spectral Angle Mapping algorithms, but not Maximum Likelihood because this algorithm needs the covariance matrix that is not included in the spectral libraries.

17.1.3 Algorithm band weight

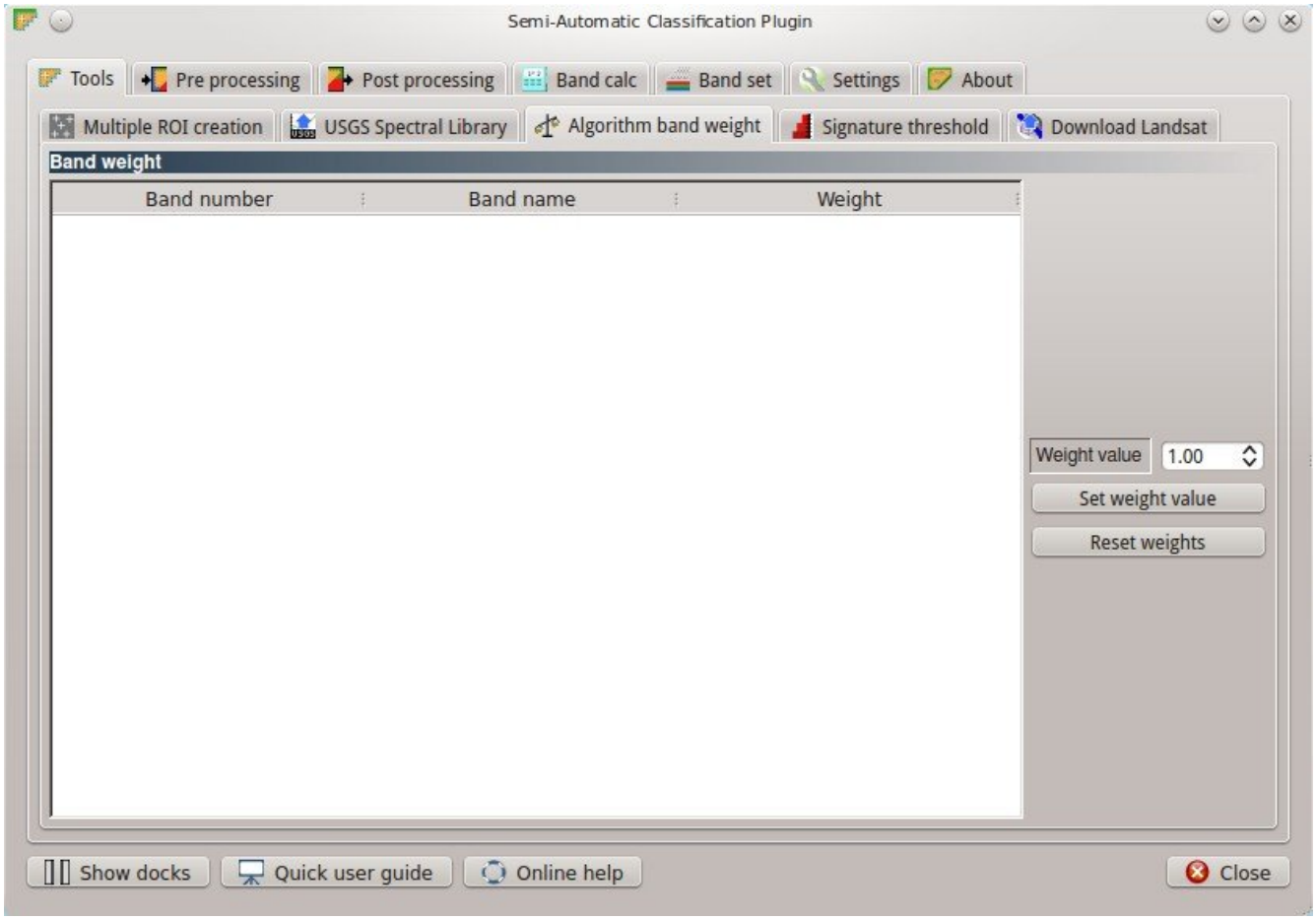


Fig. 17.3: *Algorithm band weight*

The tab `Algorithm band weight` allows for the definition of band weights that are useful for improving the spectral separability of materials. During the classification process, the spectral signature values and the corresponding band weights are multiplied thus modifying the spectral distances.

Band weight

- **Table fields:**
  - `Band number` : number of the band in the band set;

  - `Band name` : name of the band;
  - `Weight` : weight of the band; it can be edited directly or through the button `Set weight value`;
- [`Weight value`]: value of weight used with the button `Set weight value`;
- [`Set weight value`]: set the value defined in `Weight value` for all the highlighted bands in the table;
- [`Reset weights`]: reset all band weights to 1.

17.1.4 Signature threshold

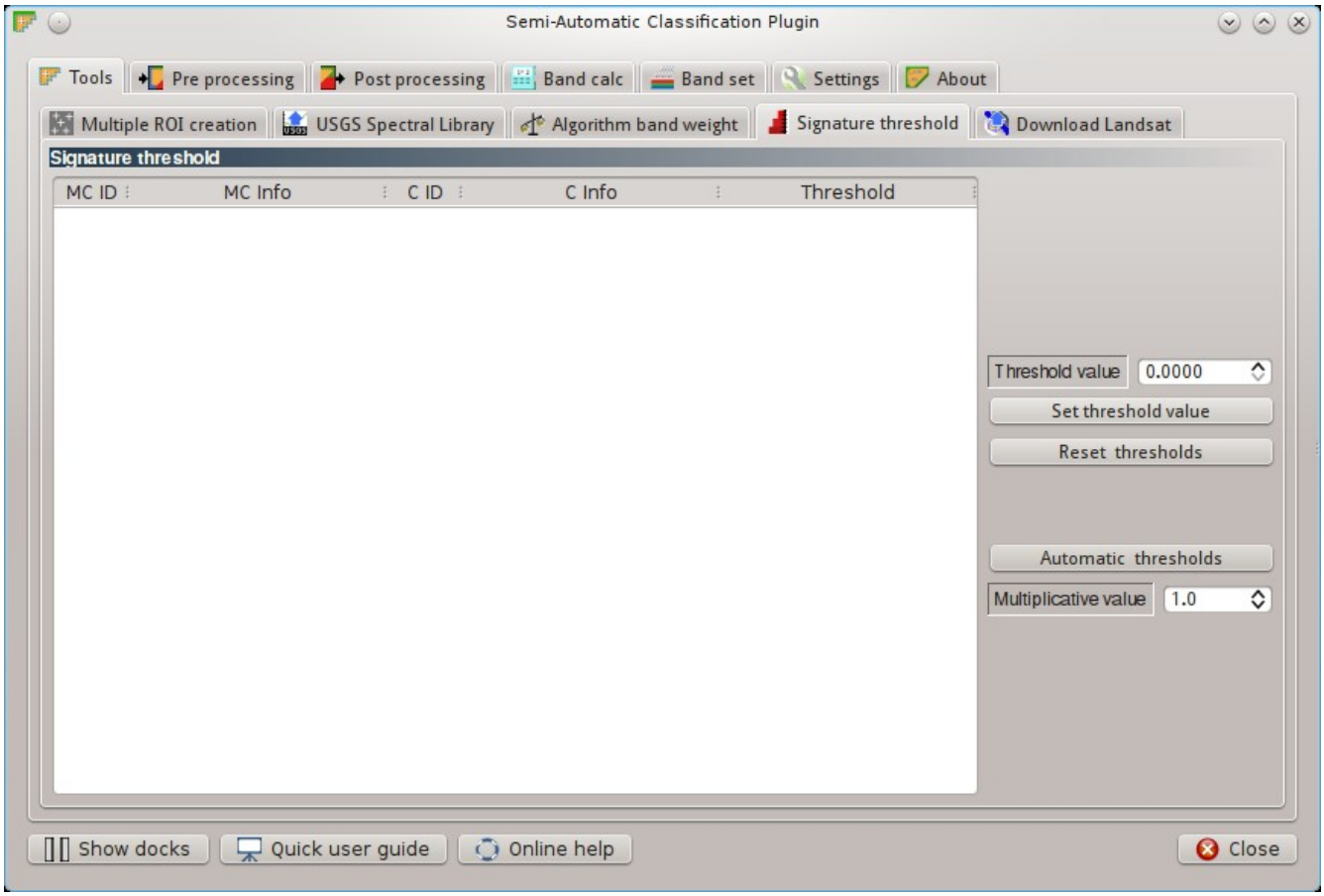


Fig. 17.4: *Signature threshold*

The tab `Signature threshold` allows for the definition of a classification threshold for each spectral signature. This is useful for improving the classification results, especially when spectral signatures are similar. Thresholds of signatures are saved in the *Signature list file* (page 95).

If threshold is 0 then no threshold is applied. Depending on the selected *Classification algorithm* (page 97) the threshold value is considered differently:

- for Minimum Distance, pixels are unclassified if distance is greater than threshold value;
- for Maximum Likelihood, pixels are unclassified if probability is less than threshold value (max 100);
- for Spectral Angle Mapping, pixels are unclassified if spectral angle distance is greater than threshold value (max 90).

Signature threshold

- **Table fields:**
  - `MC ID` : signature Macroclass ID;
  - `MC Info` : signature Macroclass Information;
  - `C ID` : signature Class ID;
  - `C Info` : signature Class Information;
  - `Threshold` : signature threshold;
- [`Threshold value`]: value of threshold used with the button `Set threshold value`;
- [`Set threshold value`]: set the value defined in `Threshold value` for all the highlighted signatures in the table;
- [`Reset thresholds`]: reset all signatures thresholds to 0 (i.e. no threshold used);
- [`Automatic thresholds`]: calculate automatically a threshold for all the highlighted signatures based on the standard deviation thereof (currently works for Minimum Distance and Spectral Angle Mapping calculating the distance or angle between mean signature and mean + standard deviation signature);
- [`Multiplicative value`]: each threshold value calculated with `Automatic thresholds` is multiplied by this value.

17.1.5 Download Landsat

The tab `Download Landsat` allows for searching and downloading the *Landsat Satellite* (page 34) 4, 5, 7, and 8 images of the whole world from the 80s to present days, freely available through the Google Earth Engine and the Amazon Web Services (AWS) . Before the use of this tool, the download of the Landsat image dabatase (about 500MB) is required, which consist of the following files (updated daily):

- http://landsat-pds.s3.amazonaws.com/scene_list.gz
- http://landsat.usgs.gov/metadata_service/bulk_metadata_files/LANDSAT_8.csv.gz
- http://landsat.usgs.gov/metadata_service/bulk_metadata_files/LANDSAT_ETM.csv.gz
- http://landsat.usgs.gov/metadata_service/bulk_metadata_files/LANDSAT_ETM_SLC_OFF.csv.gz
- http://landsat.usgs.gov/metadata_service/bulk_metadata_files/LANDSAT_TM-1980-1989.csv.gz
- http://landsat.usgs.gov/metadata_service/bulk_metadata_files/LANDSAT_TM-1990-1999.csv.gz
- http://landsat.usgs.gov/metadata_service/bulk_metadata_files/LANDSAT_TM-2000-2009.csv.gz
- http://landsat.usgs.gov/metadata_service/bulk_metadata_files/LANDSAT_TM-2010-2012.csv.gz

Images from the Amazon Web Services allows for the download of single bands.

The following video shows this tool.

http://www.youtube.com/watch?v=sI6Rz0BHW8I

Database

- [`Update database`]: update Landsat database; only the databases of the satellites checked in `Satellites` under the tool *Search* (page 110) are downloaded;
- `only Landsat 8` : if checked, only the Landsat 8 database is downloaded from the Amazon Web Services;
- [`Select database directory`] [Q]: select a directory where the Landsat database is stored; it is recommended to select a custom directory in order to prevent the database deletion when upgrading SCP;

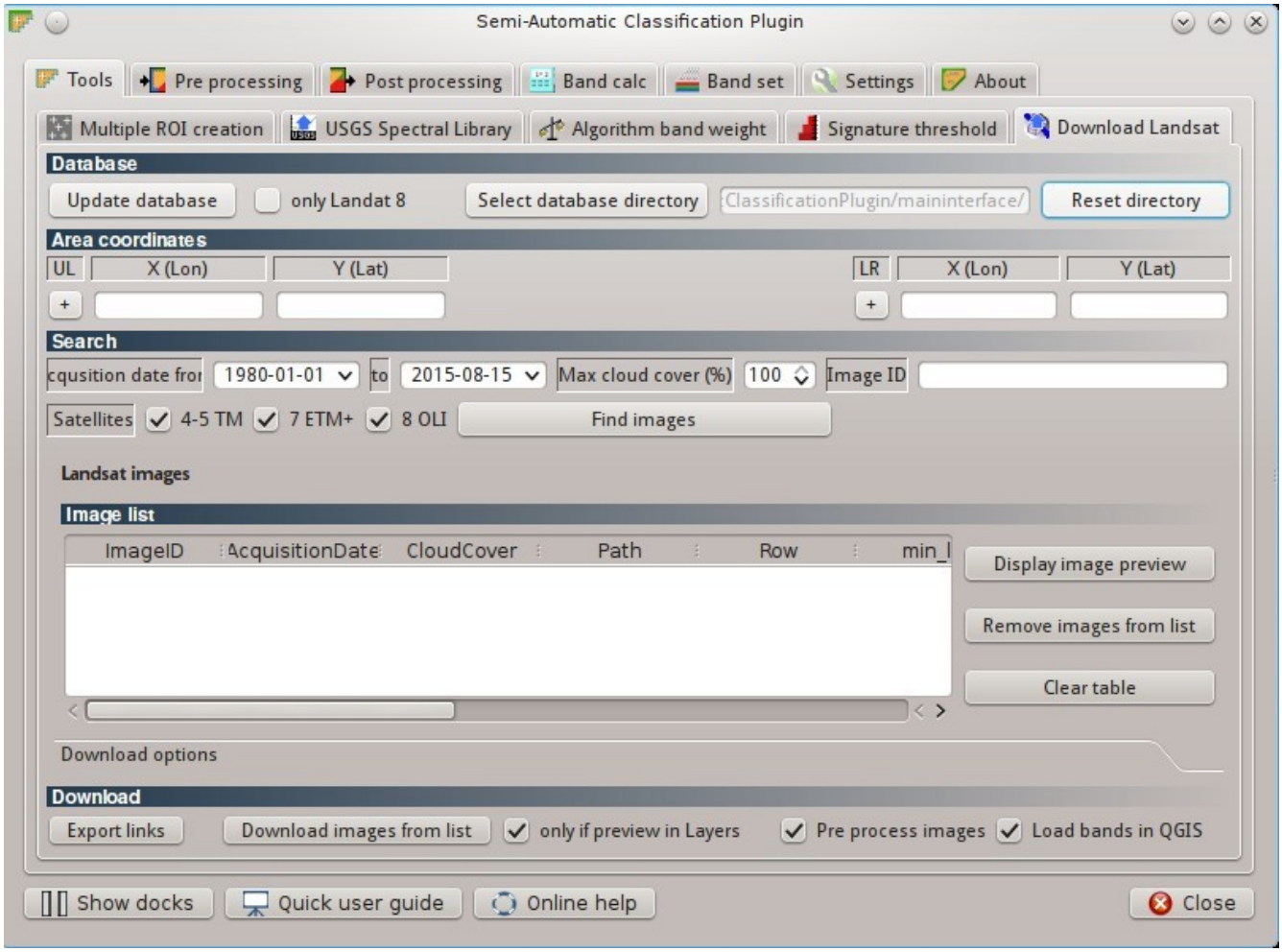


Fig. 17.5: *Download Landsat*

- [`Reset directory`]: reset the database directory to the default SCP installation directory;

Area coordinates

Define the search area.

- [+]: click the map for the definition of the Upper Left (UL) and Lower Right (LR) point coordinates (X and Y) of the rectangle defining the search area; it is possible to enter the coordinates manually;

Search

Define search settings such as the date of acquisition, maximum cloud cover, or search for specific Landsat images using the Image ID. In addition it is possible to limit the search to certain Landsat satellites.

- `Acquisition date from to` : define the range of acquisition dates; a narrow date range can make the search faster;
- `Max cloud cover (%)` : define the maximum percentage of cloud cover present in the image;
- `Image ID` : search only the Image ID of Landsat images (e.g. `LC81910312015006LGN00`); it is possible to enter multiple Image IDs separated by comma or semicolon (e.g. `LC81910312015006LGN00, LC81910312013224LGN00`);
- `Satellites` : search only the databases of the Landsat satellites checked here; deselecting unwanted satellites can make the search faster;
- [`Find images`]: start searching Landsat images; the search can last a few minutes depending on the settings thereof; results are displayed inside the table in *Landsat images* (page 110).

Landsat images

Image list

This table displays the results of the Landsat search.

- **Table fields:**
  - `ImageID` : the Landsat Image ID;
  - `AcquisitionDate` : date of acquisition of Landsat image;
  - `CloudCover` : percentage of cloud cover in the image;
  - `Path` : path of the image;
  - `Row` : row of the image;
  - `min_lat` : minimum latitude of the image;
  - `min_lon` : minimum longitude of the image;
  - `max_lat` : maximum latitude of the image;
  - `max_lon` : maximum longitude of the image;
  - `Service` : download service of the image;
  - `Preview` : URL of the image preview;
- [`Display image preview`]: display image preview of highlighted images in the map; preview are roughly georeferenced on the fly;
- [`Remove images from list`]: remove highlighted images from the list;
- [`Clear table`]: remove all images from the list;

Download options

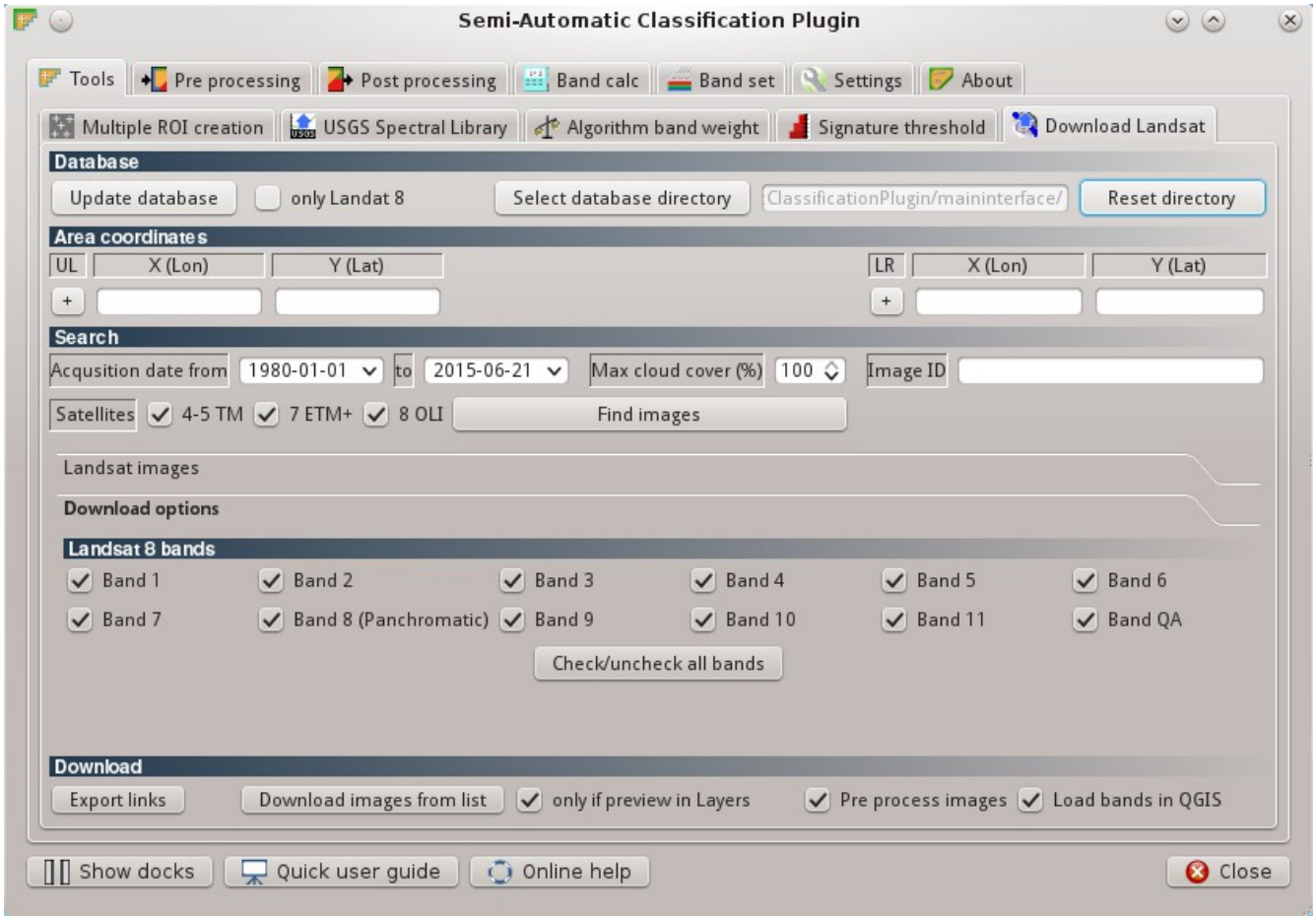


Fig. 17.6: *Download options*

Landsat 8 bands

- `Bands` : Only checked bands are downloaded (if the image is provided by the Amazon Web Services);
- [`Check/uncheck all bands`]: select or deselect all Landsat 8 bands;

Download

It is possible to download multiple images (i.e. all the images in the image list table) and select which bands to download for each image. During the download it is recommended not to interact with QGIS.

- [`Export links`]: export the download links to a text file;
- [`Download images from list`]: start the download process of all the images listed in *Landsat images* (page 110);
- `only if preview in Layers` : if checked, the download is performed only for the images listed in *Landsat images* (page 110) that are also displayed as previews in the map;
- `Pre process images` : if checked, bands are converted to reflectance (and temperature) after the download, according to the settings defined in *Landsat* (page 114);
- `Load bands in QGIS` : if checked, bands are loaded in QGIS after the download.

17.1.6 Download Sentinel

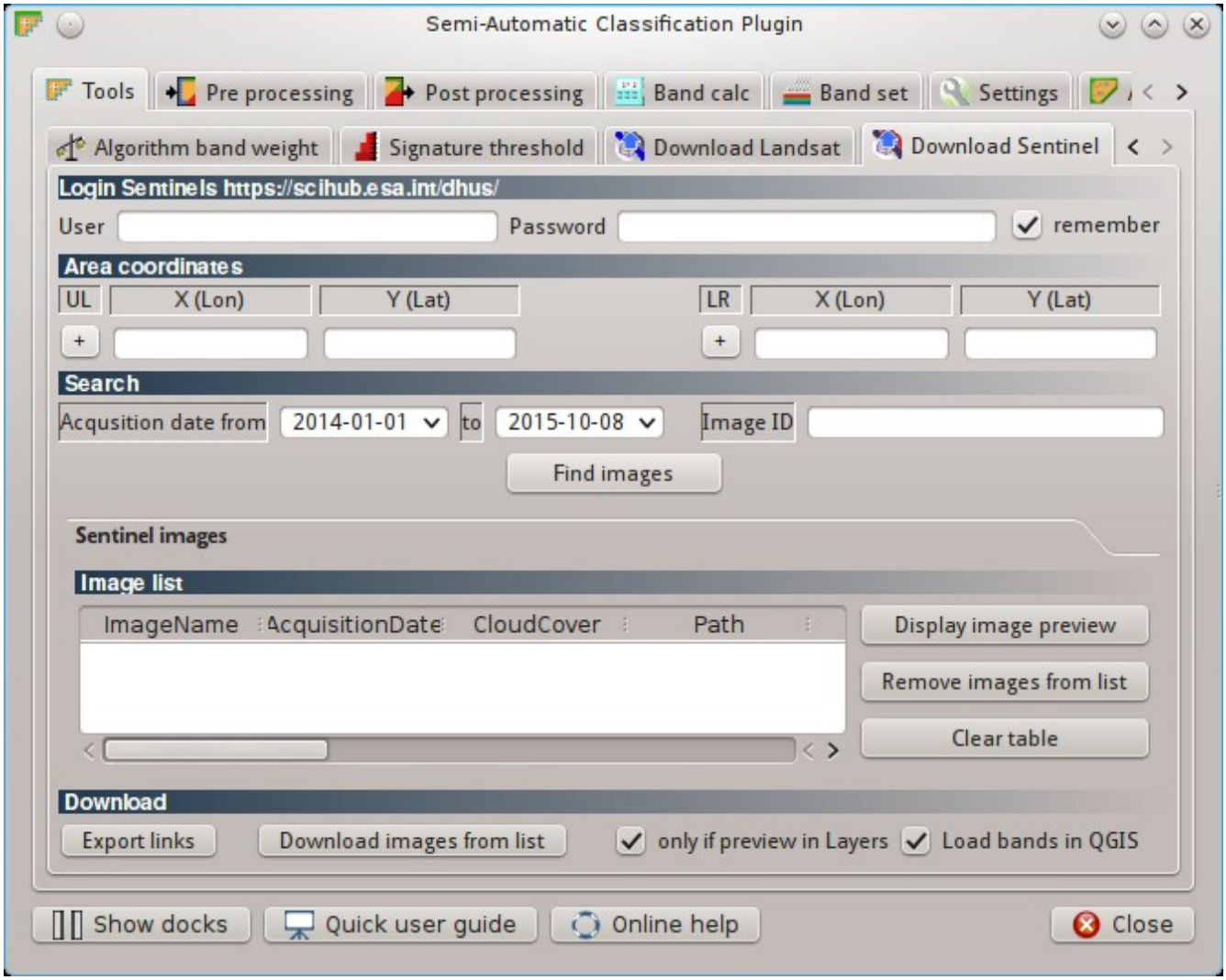


Fig. 17.7: *Download Sentinel*

The tab `Download Sentinel` allows for searching and downloading the free **Sentinel-2 images** from the ESA (European Space Agency) website https://scihub.esa.int/dhus/ . Sentinel-2 is a new European satellite developed in the frame of Copernicus land monitoring services, which acquires 13 spectral bands with the spatial resolution of 10m, 20m and 60m depending on the band (see *Sentinel-2 Satellite* (page 34)).

A free registration is required in order to access to ESA data, see https://scihub.esa.int/userguide/1SelfRegistration . The search is performed using the Data Hub API .

The following video shows this tool.

http://www.youtube.com/watch?v=fVS2Ls2bUbk

Alternative video link https://archive.org/details/video_tutorial_download_sentinel_SCP

Login Sentinels https://scihub.esa.int/dhus/

In order to access to Sentinel data a free registration is required at https://scihub.esa.int/userguide/1SelfRegistration . After the registration, enter the user name and password for searching and accessing data.

- `User` : enter the user name;
- `Password` : enter the password;
- `remember` : remember user name and password in QGIS.

Area coordinates

Define the search area.

- [+]: click the map for the definition of the Upper Left (UL) and Lower Right (LR) point coordinates (X and Y) of the rectangle defining the search area; it is possible to enter the coordinates manually;

Search

Define search settings such as the date of acquisition or search for specific Sentinel images using the Image ID or name.

- `Acquisition date from to` : define the range of acquisition dates;
- `Image ID` : search only the Image ID or name of Sentinel images;
- [`Find images`]: start searching Sentinel images; results are displayed inside the table in *Sentinel images* (page 113).

Sentinel images

Image list

This table displays the results of the Sentinel search.

- **Table fields:**
  - `ImageName` : the Sentinel image name;
  - `AcquisitionDate` : date of acquisition of Sentinel image;
  - `CloudCover` : percentage of cloud cover in the image (not used);
  - `Path` : path of the image (not used);
  - `Row` : row of the image (not used);
  - `min_lat` : minimum latitude of the image;
  - `min_lon` : minimum longitude of the image;
  - `max_lat` : maximum latitude of the image;
  - `max_lon` : maximum longitude of the image;
  - `Size` : the size of the image;
  - `Preview` : URL of the image preview;
  - `ImageID` : the Sentinel Image ID;
- [`Display image preview`]: display image preview of highlighted images in the map; preview are roughly georeferenced on the fly;
- [`Remove images from list`]: remove highlighted images from the list;
- [`Clear table`]: remove all images from the list;

Download

It is possible to download multiple images (i.e. all the images in the image list table). During the download it is recommended not to interact with QGIS.

- [`Export links`]: export the download links to a text file;
- [`Download images from list`]: start the download process of all the images listed in *Sentinel images* (page 113);
- `only if preview in Layers` : if checked, the download is performed only for the images listed in *Sentinel images* (page 113) that are also displayed as previews in the map;
- `Load bands in QGIS` : if checked, bands are loaded in QGIS after the download.

17.2 Pre processing

The `Pre processing` tab allows for the manipulation of images before the actual classification process.

17.2.1 Landsat

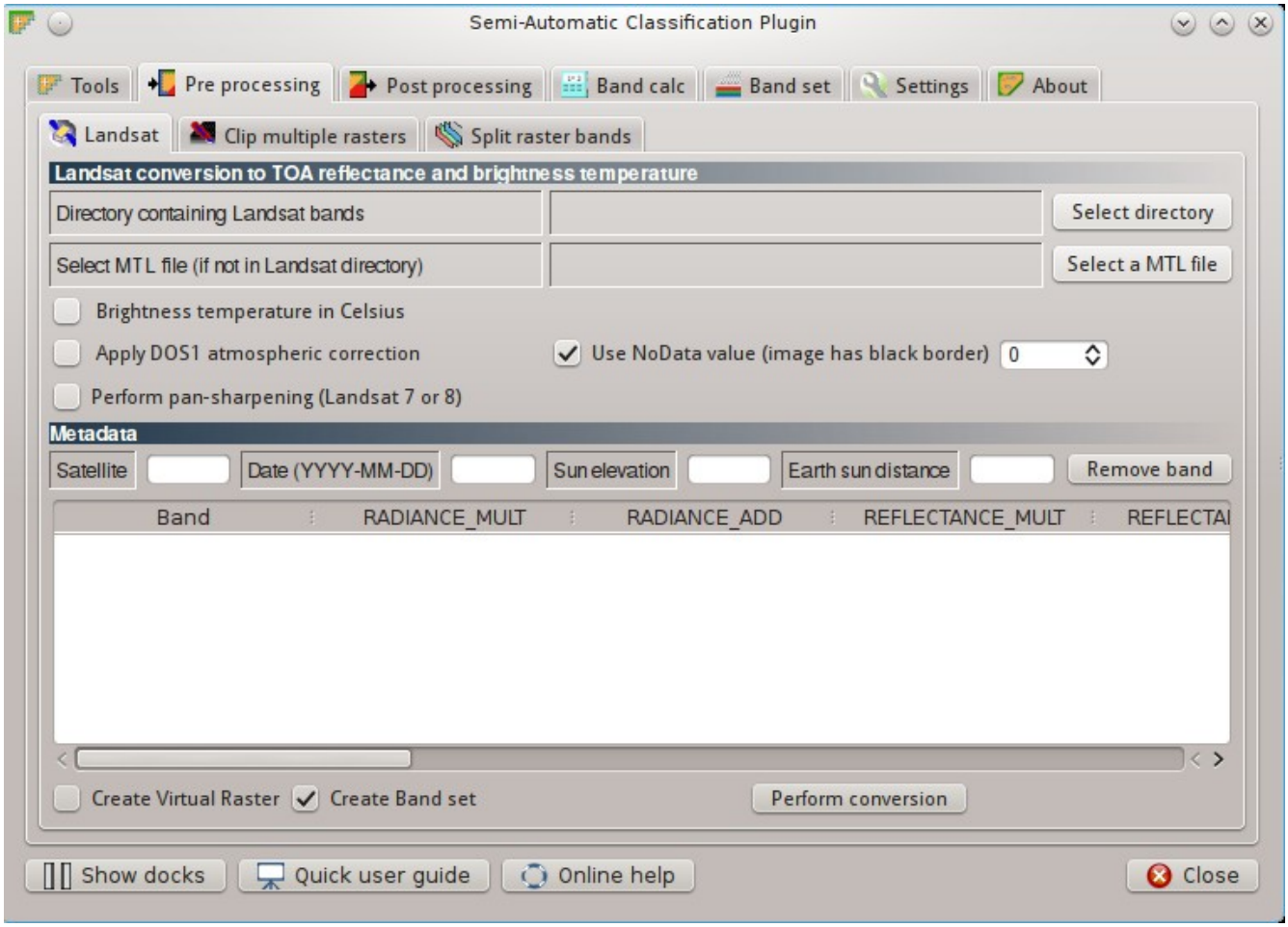


Fig. 17.8: *Landsat*

The tab `Landsat` allows for the conversion of **Landsat 1, 2, and 3 MSS** and **Landsat 4, 5, 7, and 8** images from DN (i.e. Digital Numbers) to the physical measure of Top Of Atmosphere reflectance (TOA), or the application

of a simple atmospheric correction using the DOS1 method (Dark Object Subtraction 1), which is an image-based technique (for more information about the Landsat conversion to TOA and DOS1 correction, see *Landsat image conversion to reflectance and DOS1 atmospheric correction* (page 47)).

Pan-sharpening is also available; for more information read *Pan-sharpening* (page 35).

The following video shows this tool.

http://www.youtube.com/watch?t=430&v=ImbYhiIgl1g

Alternative video link https://archive.org/details/video_basic_tutorial_2?start=430

Landsat conversion to TOA reflectance and brightness temperature

- [`Select directory`]: select the `Directory containing Landsat bands`; names of Landsat bands must end with the respective number; if the metafile (a .txt or .met file whit the suffix MTL) is inside this directory then *Metadata* (page 115) are filled;
- [`Select directory`] [optional]: `Select MTL file` if the metafile (a .txt or .met file whit the suffix MTL) is in a directory different than the `Directory containing Landsat bands`;
- `Brightness temperature in Celsius` : if checked, convert brightness temperature to Celsius (if a Landsat thermal band is listed in *Metadata* (page 115)); if unchecked temperature is in Kelvin;
- `Apply DOS1 atmospheric correction` : if checked, the *DOS1 Correction* (page 48) is applied to all the bands (thermal bands excluded);
- `Use NoData value (image has black border)` : if checked, pixels having 'NoData' value are not counted during the DOS1 calculation of DNmin; it is useful when Landsat image has a black border (usually pixel value = 0).
- `Perform pan-sharpening` : if checked, a Brovey Transform is applied for the *Pan-sharpening* (page 35) of Landsat bands.

Metadata

All the bands found in the `Directory containing Landsat bands` are listed in the metadata table. Metadata for the corresponding bands are automatically filled using the metafile found inside the `Directory containing Landsat bands` or defined in `Select MTL file`. In addition, it is possible to edit the metadata manually. For information about metadata fields read this page and this one .

- < `Satellite` >: satellite name (e.g. Landsat8);
- < `Date` >: date acquired (e.g. 2013-04-15);
- < `Sun elevation` >: Sun elevation in degrees;
- < `Earth sun distance` >: Earth sun distance in astronomical units (automatically calculated if `Date` is filled;
- [`Remove band`]: remove highlighted bands from the table list;
- **Table fields:**
  - `RADIANCE_MULT` : multiplicative rescaling factor;
  - `RADIANCE_ADD` : additive rescaling factor;
  - `REFLECTANCE_MULT` : multiplicative rescaling factor;
  - `REFLECTANCE_ADD` : additive rescaling factor;
  - `RADIANCE_MAXIMUM` : radiance maximum;
  - `REFLECTANCE_MAXIMUM` : reflectance maximum;
  - `K1_CONSTANT` : thermal conversion constant;

  - `K2_CONSTANT` : thermal conversion constant;
  - `LMAX` : spectral radiance that is scaled to QCALMAX;
  - `LMIN` : spectral radiance that is scaled to QCALMIN;
  - `QCALMAX` : minimum quantized calibrated pixel value;
  - `QCALMIN` : maximum quantized calibrated pixel value;

- `Create Virtual Raster` : if checked, a virtual raster named `landast.vrt` is created and loaded in QGIS after the conversion;
- `Create Band set` : if checked, the Band set is created using converted bands after that `Perform conversion` is clicked;
- [`Perform conversion`]: select an output directory and start the conversion process; only bands listed in the Metadata table are converted; converted Landsat bands are saved in the output directory with the prefix `RT_`, and automatically loaded in QGIS.

17.2.2 Clip multiple rasters

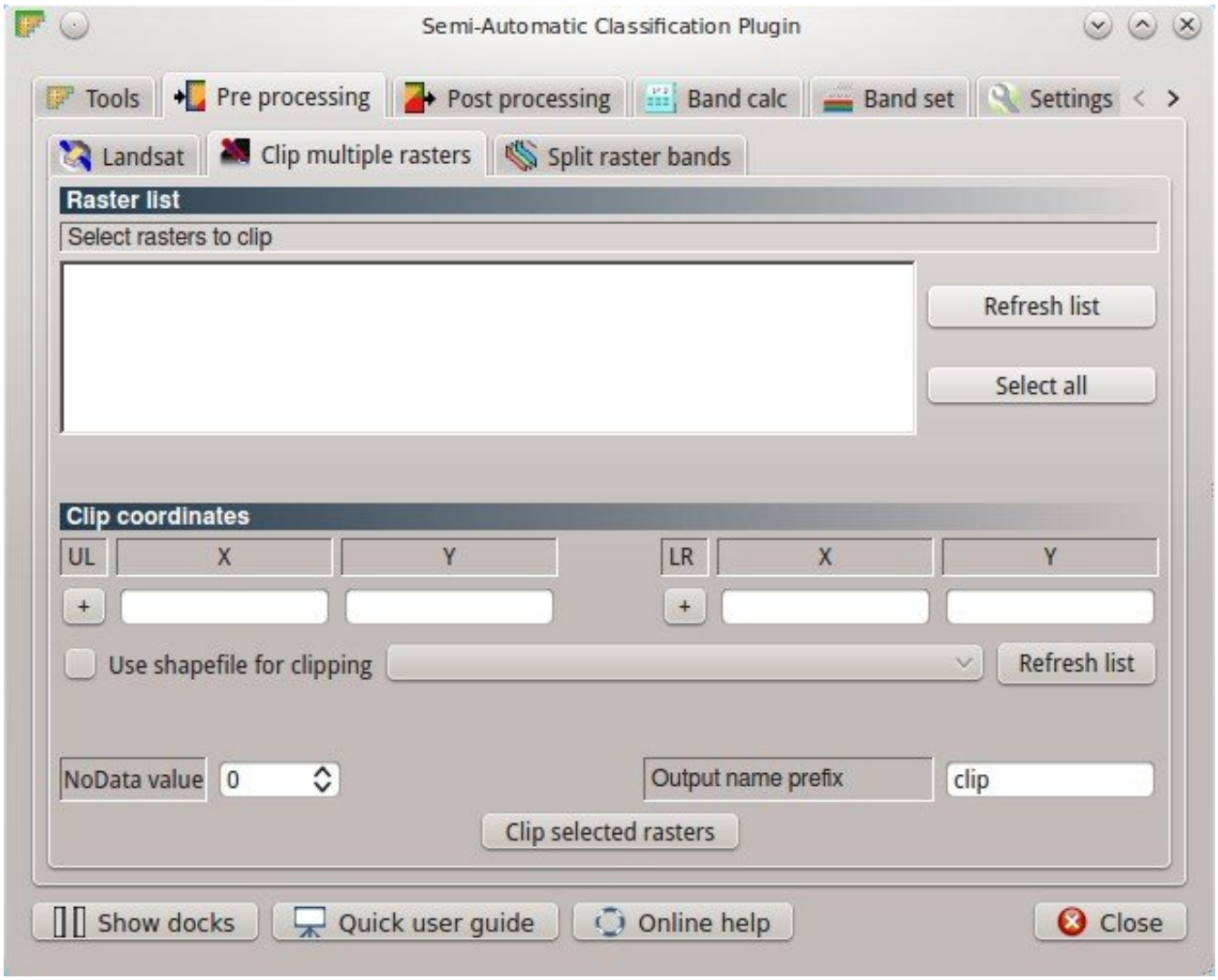


Fig. 17.9: *Clip multiple rasters*

The tab `Clip multiple rasters` allows for cutting several image bands at once, using a rectangle defined with point coordinates or a boundary defined with a shapefile.

The following video shows this tool.

http://www.youtube.com/watch?t=650&v=ImbYhiIgl1g

Alternative video link https://archive.org/details/video_basic_tutorial_2?start=650

Raster list

- [`Refresh list`]: refresh layer list;
- [`Select all`]: select all the rasters to be clipped.

Clip coordinates

- [+]: click the map for the definition of the Upper Left (UL) and Lower Right (LR) point coordinates (X and Y) of the rectangle used for clipping; it is possible to enter the coordinates manually;
- `Use shapefile for clipping`: if checked, use the selected shapefile (already loaded in QGIS) for clipping, overriding point coordinates;
- < `No data value` >: set the value for 'NoData' pixels (e.g. pixel outside the clipped area);
- < `Output name prefix` >: set the prefix for output file names;
- [`Clip selected rasters`]: choose the output destination and clip selected rasters; only rasters selected in the *Raster list* (page 117) are clipped and automatically loaded in QGIS.

17.2.3 Split raster bands

Split a multiband raster to single bands.

- `Select a multiband raster`: select a multiband raster already loaded in QGIS;
- < `Output name prefix` >: set the prefix for output file names;
- [`Split selected rasters`]: choose the output destination and split selected raster; output bands are automatically loaded in QGIS.

Raster input

17.3 Post processing

The tab `Post processing` provides several functions that can be applied to the classification output.

17.3.1 Accuracy

The tab `Accuracy` allows for the validation of a classification (read *Accuracy Assessment* (page 44)). Classification is compared to a reference raster or reference shapefile (which is automatically converted to raster). If a shapefile is selected as reference, it is possible to choose a field describing class values.

Several statistics are calculated such as overall accuracy, user's accuracy, producer's accuracy, and Kappa hat. The output is an `error raster` that is a .tif file showing the errors in the map, where pixel values represent the categories of comparison (i.e. combinations identified by the `ErrorMatrixCode` in the error matrix) between the classification and reference. Also, a text file containing the error matrix (i.e. a .csv file separated by tab) is created with the same name defined for the .tif file.

The following video shows this tool.

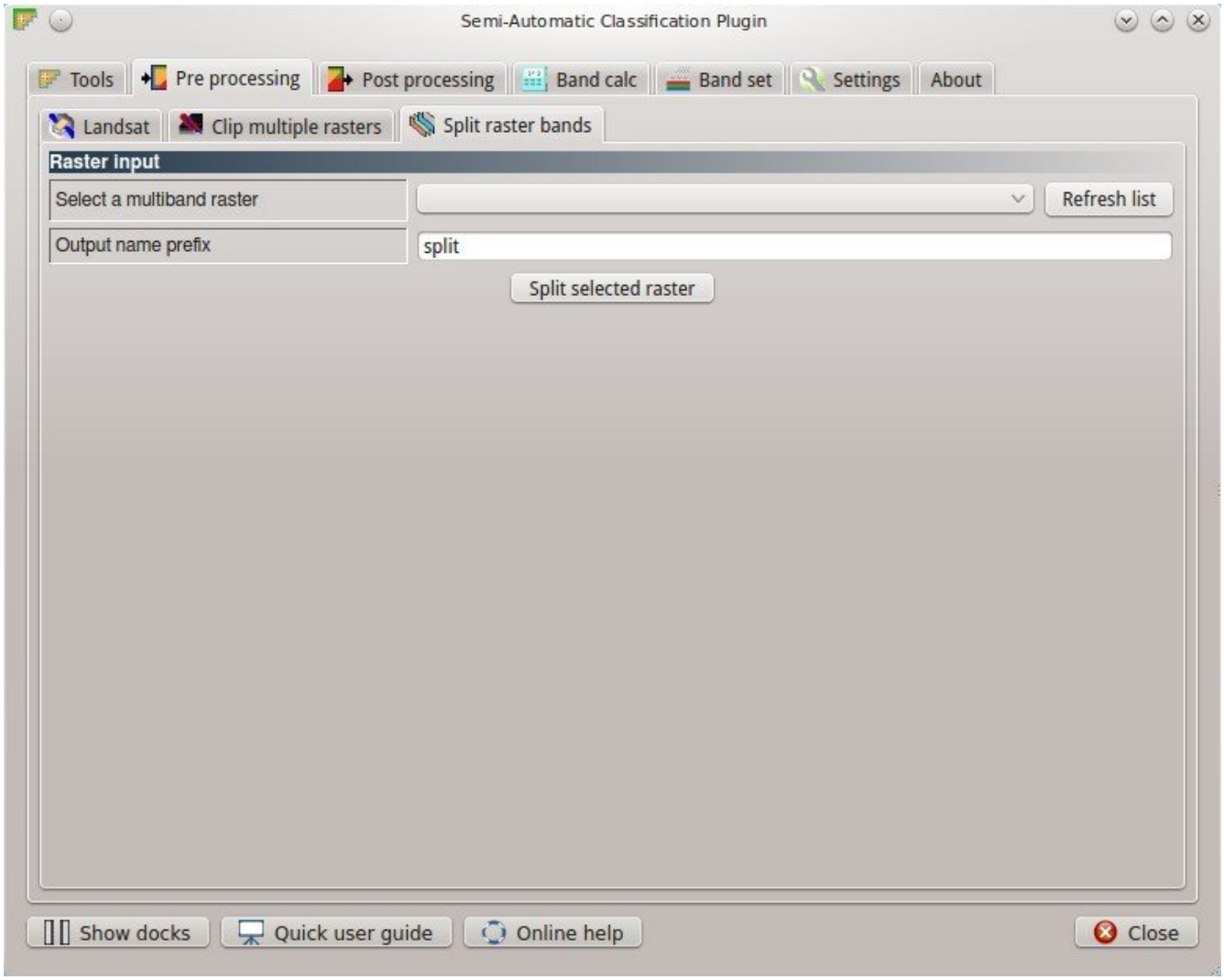


Fig. 17.10: *Split raster bands*

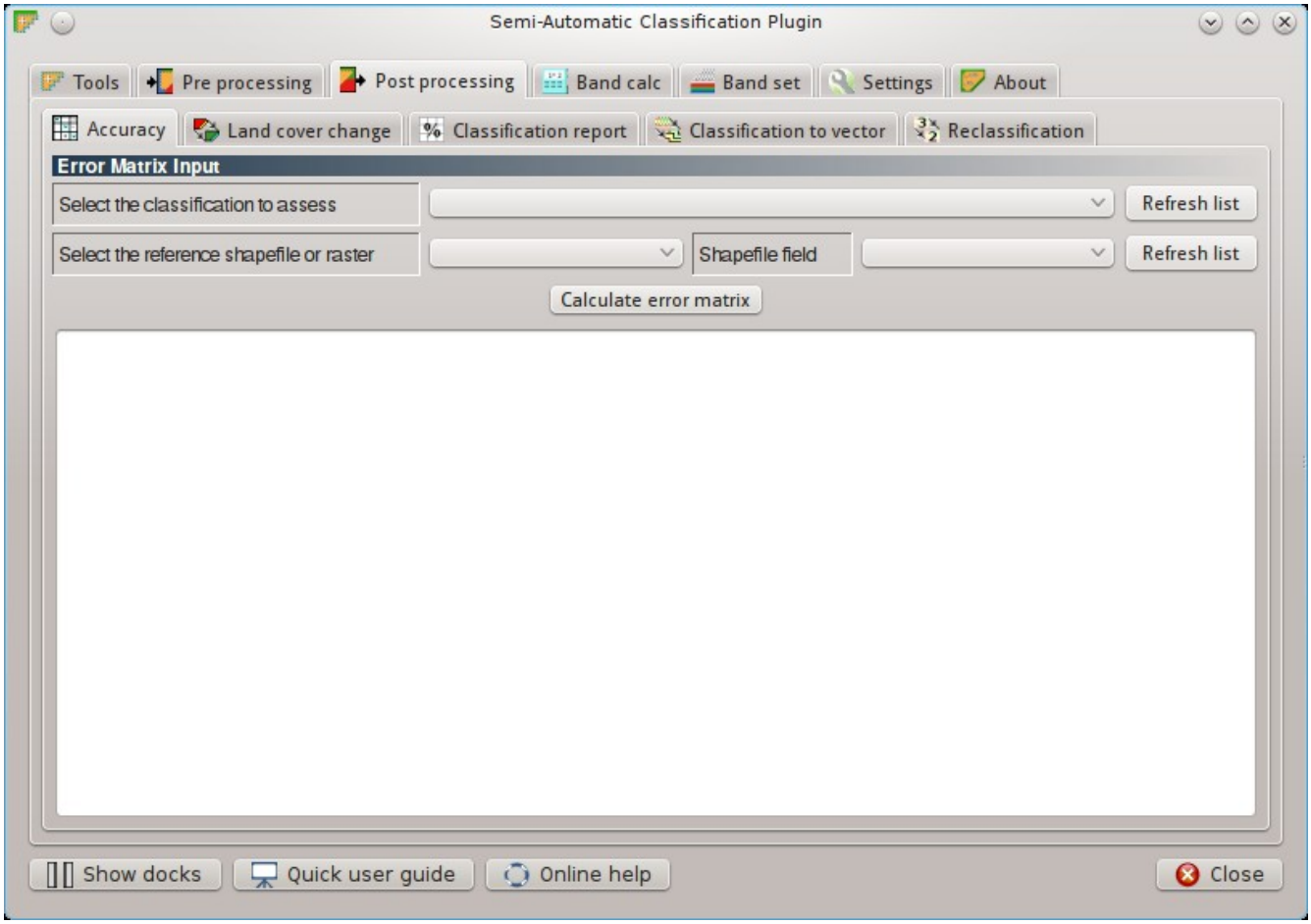


Fig. 17.11: *Accuracy*

http://www.youtube.com/watch?t=2780&v=acxmIrM-Qns

Alternative video link https://archive.org/details/video_tutorial_Landsat_mosaic_ENG?start=2780

Error Matrix Input

- `Select the classification to assess` : select a classification raster;
- `Select the reference shapefile or raster` : select a raster or a shapefile, used as reference layer (ground truth) for the accuracy assessment;
- `Shapefile field` : if a shapefile is selected as reference, select a shapefile field containing numeric class values;
- [`Refresh list`]: refresh layer list;
- [`Calculate error matrix`]: choose the output destination and start the calculation; the error matrix is displayed in the tab frame and the `error raster` is loaded in QGIS.

17.3.2 Land cover change

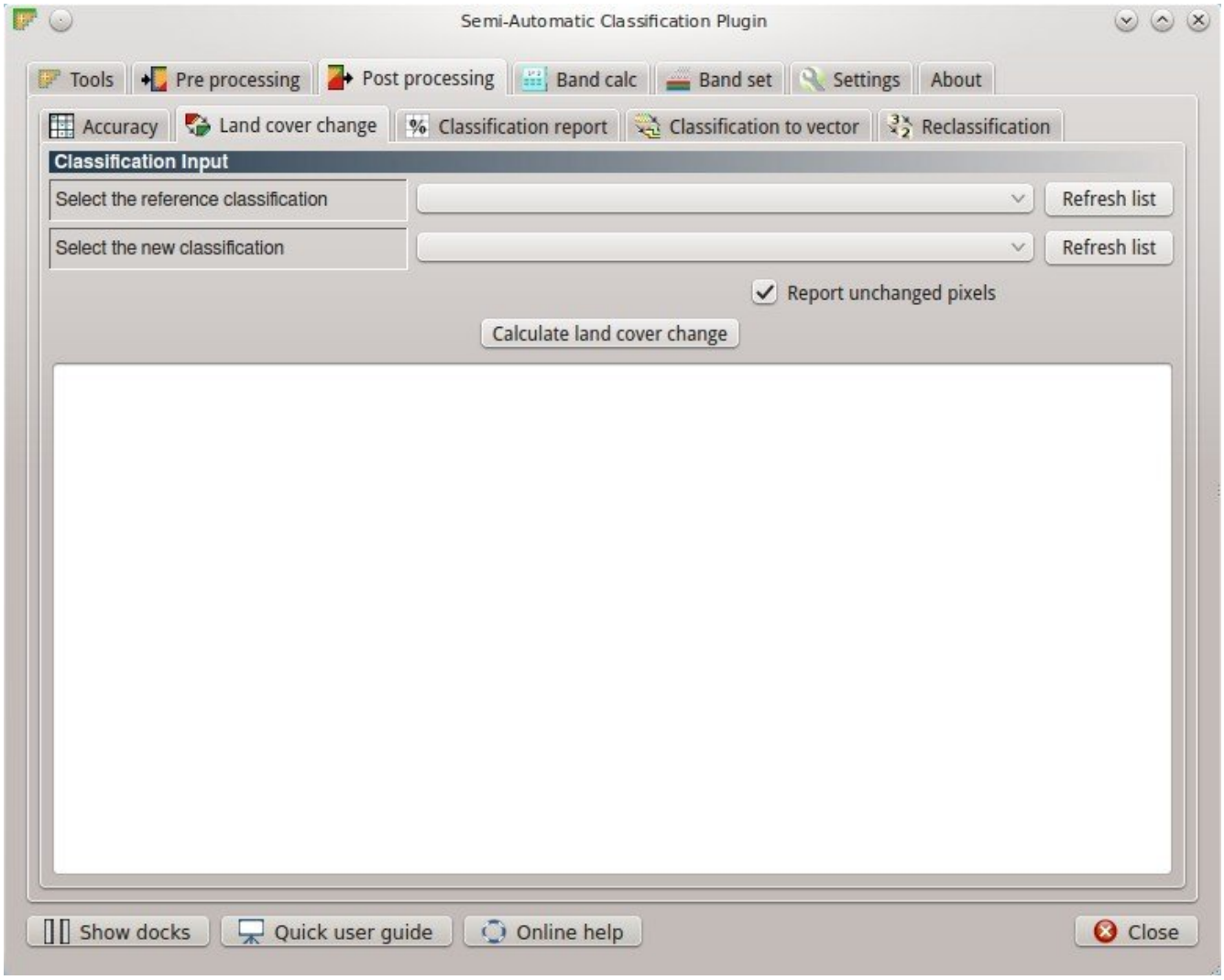


Fig. 17.12: *Land cover change*

The tab `Land cover change` allows for the comparison between two classifications in order to assess land cover changes. Output is a `land cover change raster` (i.e. a .tif file showing the changes in the map, where each pixel represents a category of comparison (i.e. combinations) between the two classifications, which is the `ChangeCode` in the land cover change statistics) and a text file containing the land cover change statistics (i.e. a .csv file separated by tab, with the same name defined for the .tif file).

The following video shows this tool.

http://www.youtube.com/watch?t=834&v=TCBpKvr3AI8

Classification input

- `Select the reference classification` : select a reference classification raster (already loaded in QGIS);
- `Select the new classification` : select a new classification raster (already loaded in QGIS), to be compared with the reference classification;
- `Report unchanged pixels`: if checked, report also unchanged pixels (having the same value in both classifications);
- [`Calculate land cover change`]: choose the output destination and start the calculation; the land cover change statistics are displayed in the tab frame and the `land cover change raster` is loaded in QGIS.

17.3.3 Classification report

The tab `Classification report` allows for the calculation of class statistics as number of pixels, percentage and area (area unit is defined from the image itself).

The following video shows this tool.

http://www.youtube.com/watch?t=3070&v=acxmIrM-Qns

Alternative video link https://archive.org/details/video_tutorial_Landsat_mosaic_ENG?start=3070

Classification input

- `Select the classification` : select a classification raster (already loaded in QGIS);
- [`Refresh list`]: refresh layer list;
- `Use NoData value` : if checked, 'NoData' value will be excluded from the report;
- [`Calculate classification report`]: calculate the report and display it in the tab frame;
- [`Save report to file`]: save the report to a .csv file.

17.3.4 Classification to vector

The `Classification to vector` allows for the conversion of a classification to shapefile.

Classification input

- `Select the classification` : select a classification raster (already loaded in QGIS);
- [`Refresh list`]: refresh layer list;
- `Use code from Signature list` : if checked, color and class information are defined from *Signature list* (page 95), according to the selection between `MC ID` and `C ID` in the combobox;

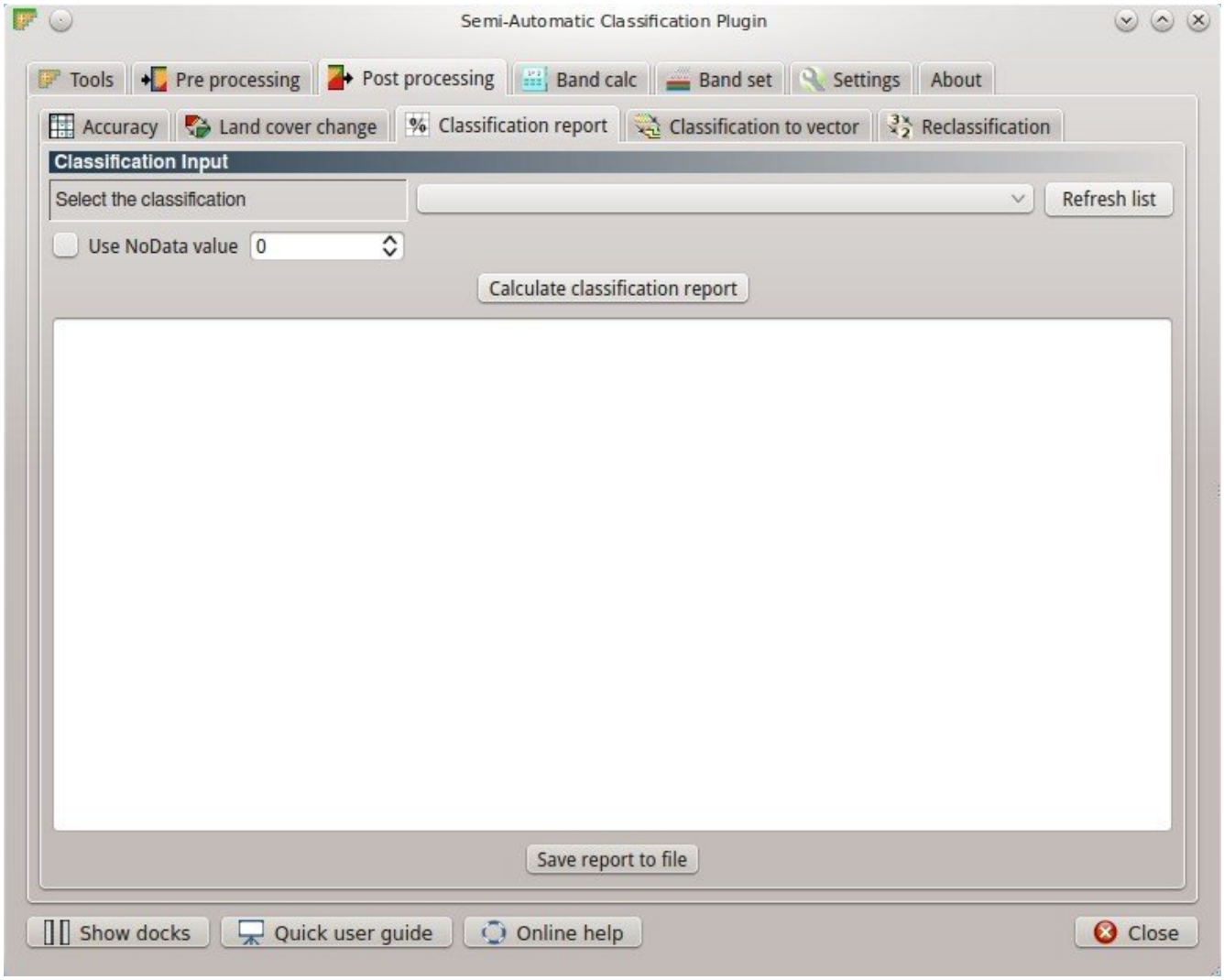


Fig. 17.13: *Classification report*

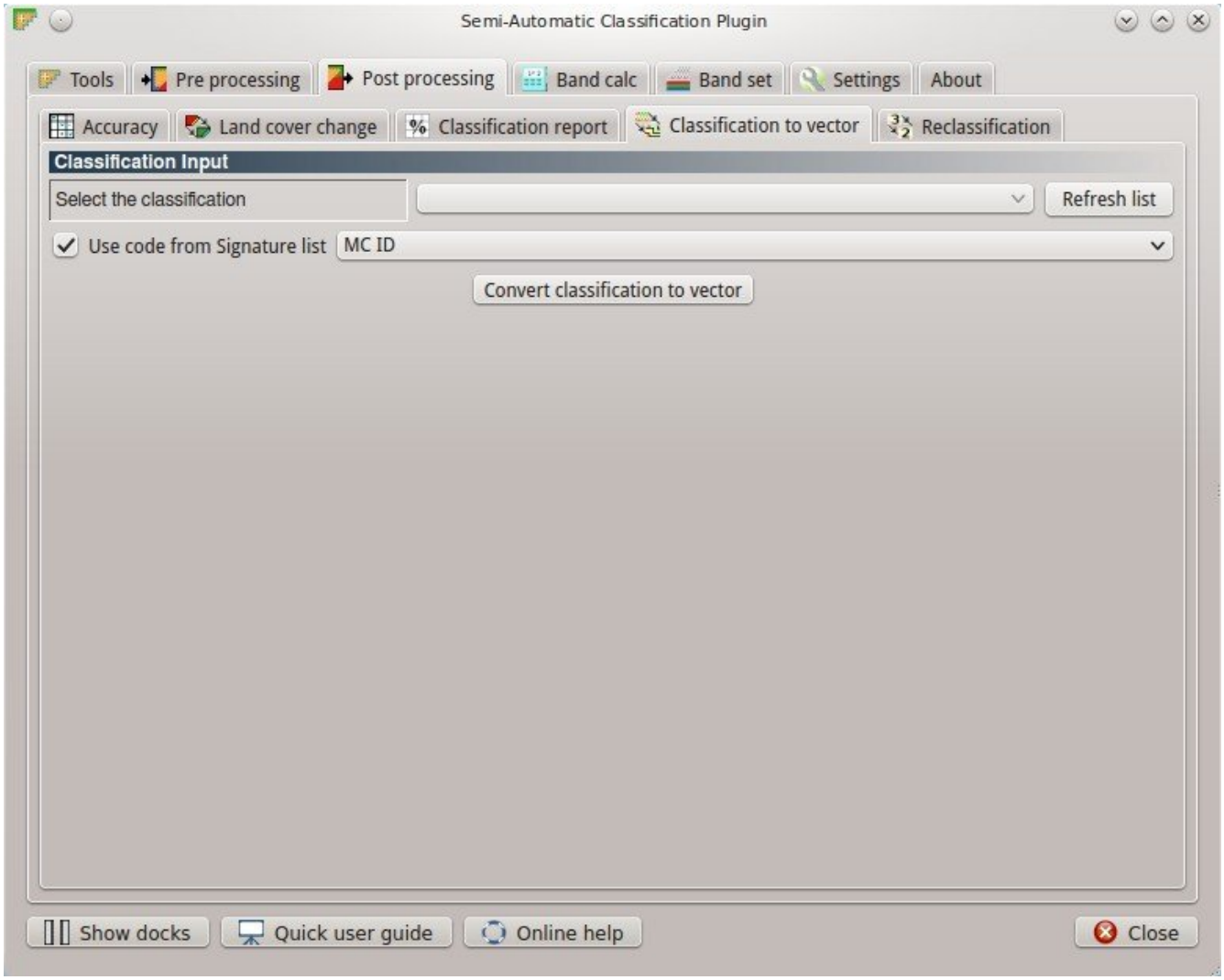


Fig. 17.14: *Classification to vector*

17.3.5 Reclassification

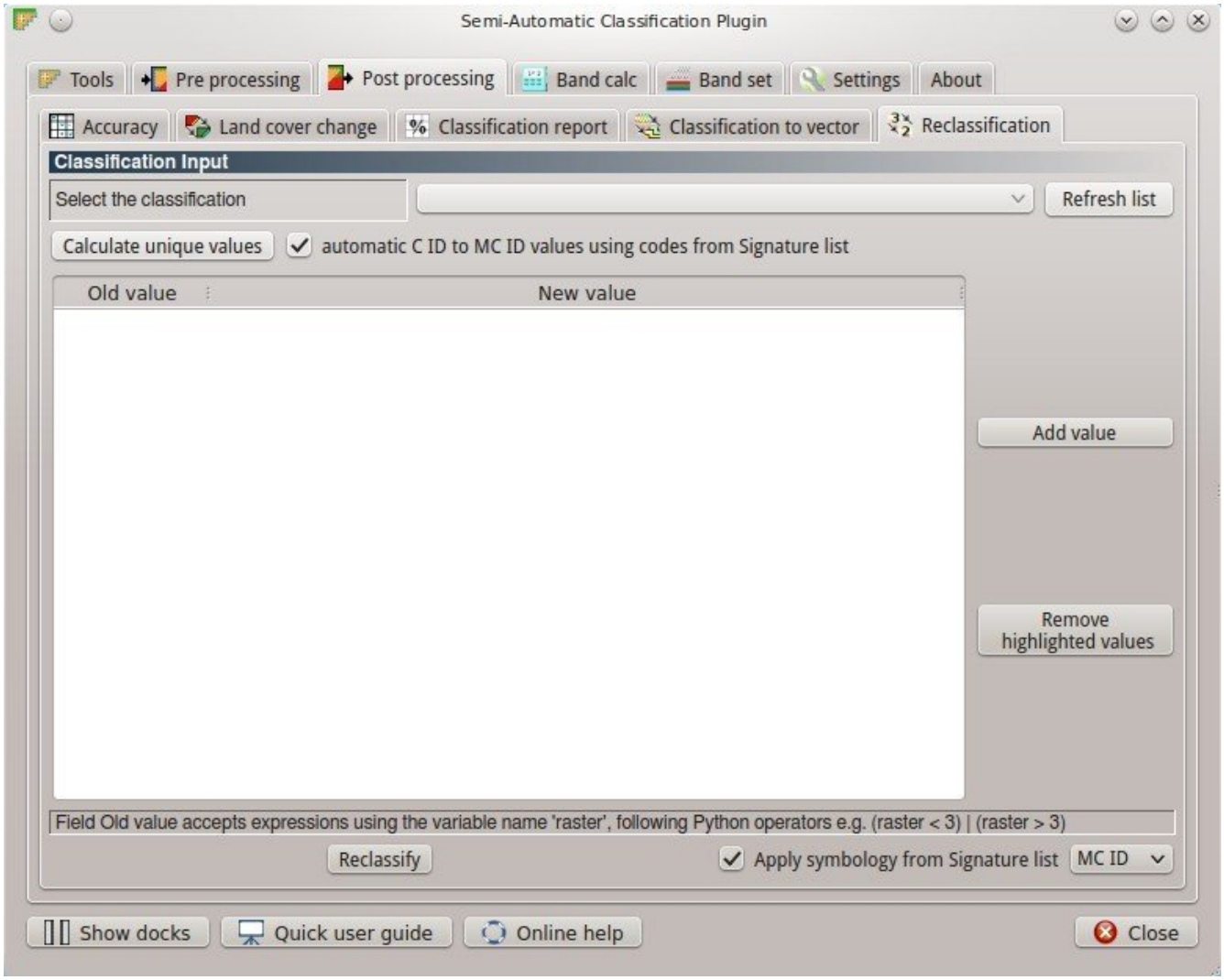


Fig. 17.15: *Reclassification*

The tab `Reclassification` allows for the reclassification (i.e. assigning a new class code to classification pixels). In particular, it is useful for converting C ID to MC ID values.

Classification input

- `Select the classification` : select a classification raster (already loaded in QGIS);
- [`Refresh list`]: refresh layer list;
- [`Calculate unique values`]: calculate unique values in the classification and fill the reclassification table;
- `automatic C ID to MC ID values using codes from Signature list`: if checked, the reclassification table is filled according to the *Signature list* (page 95) when `Calculate unique values` is clicked;
- **Table fields:**
  - `Old value` : set the expression defining old values to be reclassified; `Old value` can be a value or an expressions defined using the variable name `raster` (custom names can be defined

in *Variable name for expressions (tab Reclassification)* (page 131)), following Python operators (e.g. `raster > 3` select all pixels having value > 3 ; `raster > 5 | raster < 2` select all pixels having value > 5 or < 2 ; `raster >= 2 & raster <= 5` select all pixel values between 2 and 5);

  - `New value` : set the new value for the old values defined in `Old value`;

- [`Add value`]: add a row to the table;
- [`Remove highlighted values`]: remove highlighted rows from the table;
- [`Reclassify`]: choose the output destination and start the calculation; reclassified raster is loaded in QGIS;
- `Apply symbology from Signature list` : if checked, color and class information are defined from *Signature list* (page 95), according to the selection between `MC ID` and `C ID` in the combobox.

17.4 Band calc

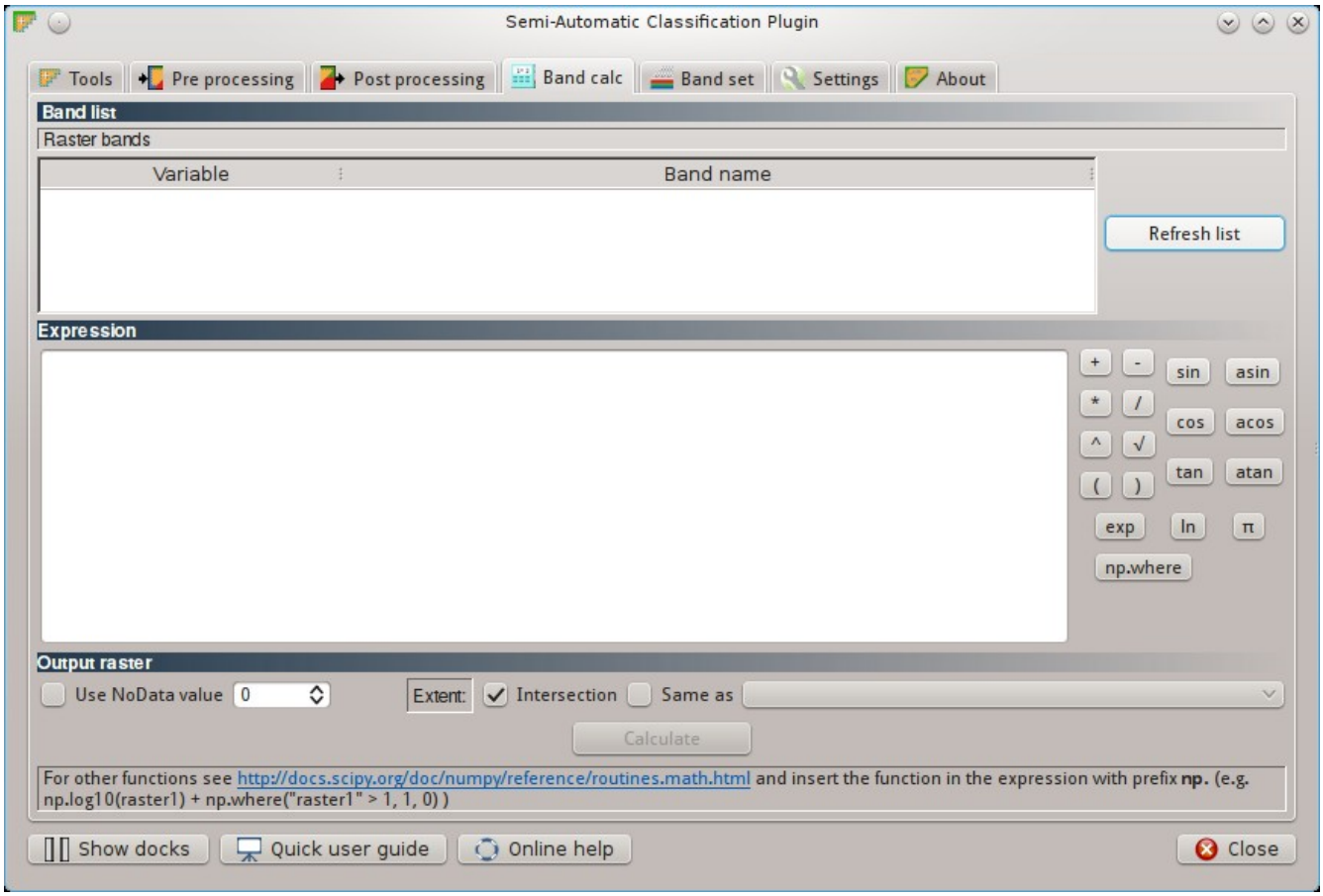


Fig. 17.16: *Band calc tab*

The `Band calc` allows for the **raster calculation for bands** (i.e. calculation of pixel values) using NumPy functions . Raster bands must be already loaded in QGIS. Input rasters must be in the same projection.

The following video shows this tool.

http://www.youtube.com/watch?v=vjKX00jML64

Alternative video link https://archive.org/details/video_band_calc

17.4.1 Band list

`Band list` is a list of single band rasters loaded in QGIS.

- **Fields of Raster bands table:**
  - `Variable` : automatic variable name for the specific band (e.g. raster1);
  - `Band name` : band name (i.e. the layer name in QGIS);
- [`Refresh list`]: refresh image list;

17.4.2 Expression

Enter a mathematical expression for bands. In particular, NumPy functions can be used with the prefix *np.* (e.g. `np.log10(raster1)`). For a list of NumPy functions see the NumPy page .

The expression can work both with `Variable` and `Band name` between quotes. Also, bands in the *Band set* (page 127) can be referenced directly; for example `bandset#b1` refers to band 1 of the Band set. Double click on any item in the *Band list* (page 126) for adding its name to the expression.

If text in the `Expression` is green, then the syntax is correct; if text is red, then the syntax is incorrect and it is not possible to execute the calculation.

It is possible to enter multiple expressions separated by newlines like in the following example:

```
raster1 + raster2
raster3 - raster4
```

The above example calculates two new rasters in the output directory with the suffix `_1` (e.g. `output_1`) for the first expression and `_2` (e.g. `output_2`) for the second expression. The following buttons are available:

- [+]: plus;
- [−]: minus;
- [*]: product;
- [/]: ratio;
- [^]: power;
- [V]: square-root;
- [( ]: open parenthesis;
- [ )]: close parenthesis;
- [`exp`]: natural exponential;
- [`sin`]: sine;
- [`asin`]: inverse sine;
- [`cos`]: cosine;
- [`acos`]: inverse cosine;
- [`tan`]: tangent;
- [`atan`]: inverse tangent;
- [`log`]: natural logarithm;
- [π]: pi;
- [`np.where`]: conditional expression with the syntax `np.where( condition , value if true, value if false)` ;

17.4.3 Output raster

The output raster is a .tif file, with the same spatial resolution and projection of input rasters; if input rasters have different spatial resolutions, then the highest resolution (i.e. minimum pixel size) is used for output raster.

- `Use NoData value` : if checked, pixels equal to NoData value will be excluded from the output raster;
- **Extent:**
  - `Intersection` : if checked, the extent of output raster equals the intersection of input raster extents (i.e. minimum extent); if unchecked, the output raster extent will include the extents of input rasters;
  - `Same as` : if checked, the extent of output raster equals the extent of selected layer;
- [`Calculate`]: if `Expression` is green, choose the output destination and start the calculation; if multiple expressions are entered, then multiple outputs are created with the same name and a numerical suffix according to the numerical order of expressions.

17.5 Band set

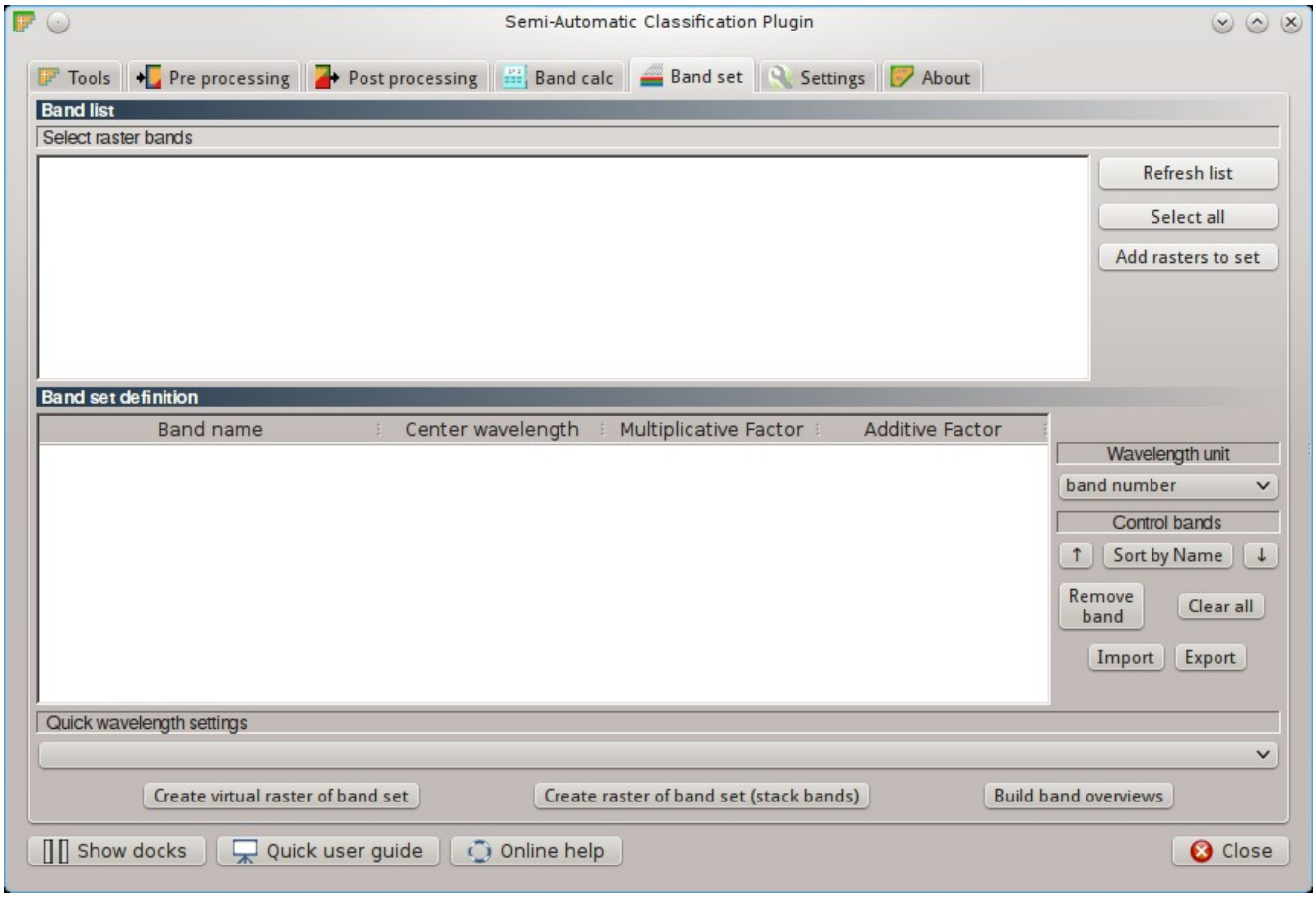


Fig. 17.17: *Band set*

The tab `Band set` allows for the definition of a set of single band rasters loaded in QGIS, used as `Input image`. The `Center wavelength` of bands can be defined, which is required in order to calculate properly the spectral signatures.

If a band set of single band rasters is defined, then the item `<< band set >>` will be listed in the *Toolbar* (page 87) as `Input image`.

The `Band set` is stored in the QGIS project.

17.5.1 Band list

List of single band rasters loaded in QGIS.

- [`Refresh list`]: refresh raster band list;
- [`Select all`]: select all raster bands;
- [`Add rasters to set`]: add selected rasters to the band set.

17.5.2 Band set definition

Definition of bands composing the `Input image` .

Although it is recommended to define the `Center wavelength` of bands, it is possible to assign the band number instead of the wavelength. Of course, the *USGS Spectral Library* (page 104) will not be useful, but the ROI collection and the classification process will still be working. It is possible to define a multiplicative rescaling factor and additive rescaling factor for each band (for instance using the values in Landsat metadata), which allow for on the fly conversion to TOA while calculating spectral signatures or classifying.

- **Table fields:**
  - `Band name` [P]: name of the band; this element cannot be edited;
  - `Center wavelength` [P]: center of the wavelength of the band; enter a value;
  - `Multiplicative Factor` [P]: multiplicative rescaling factor; enter a value;
  - `Additive Factor` [P]: additive rescaling factor; enter a value;
- **`Wavelength unit` [P]: select the wavelength unit among:**
  - [`Band number`]: no unit, only band number;
  - [μm]: micrometres;
  - [`nm`]: nanometres;
- **`Control bands`:**
  - [↑]: move highlighted bands upward;
  - [`Sort by name`]: sort automatically bands by name, giving priority to the ending numbers of name;
  - [↓]: move highlighted bands downward;
  - [`Remove band`]: remove highlighted bands from the band set;
  - [`Clear all`]: clear all bands from band set;
  - [`Import`]: import a previously saved band set from file;
  - [`Export`]: export the band set to a file.
- **`Quick wavelength settings` [optional]: rapid definition of band center wavelength for the following satellite se**
  - GeoEye-1;
  - Landsat 8 OLI;
  - Landsat 7 ETM+;
  - Landsat 5 TM;
  - Landsat 4 TM;

  - Landsat 1, 2, and 3 MSS;
  - Pleiades;
  - QuickBird;
  - RapidEye;
  - Sentinel-2;
  - SPOT 4;
  - SPOT 5;
  - SPOT 6;
  - WorldView-2;
  - WorldView-3.

- [`Create virtual raster of band set`]: create a virtual raster of bands;
- [`Create raster of band set (stack bands)`]: stack all the bands and create a unique .tif raster;
- [`Build band overviews`]: build raster overviews (i.e. pyramids) for improving display performance.

17.6 Settings

The tab `Settings` allows for the customization of SCP settings.

17.6.1 Settings: Interface

Customization of the interface.

Field names of training shapefile

Set the names of fields in the *Training shapefile* (page 89) . Changing field names according to the fields of an existing shapefile is effective for using external shapefiles as *Training shapefile* (page 89) (see this video).

- `MC ID field` [Q]: name of the Macroclass ID field (default is `MC_ID`);
- `MC Info field` [Q]: name of the Macroclass Information field (default is `MC_info`);
- `C ID field` [Q]: name of the Class ID field (default is `C_ID`);
- `C Info field` [Q]: name of the Class Information field (default is `C_info`);
- [`Reset field names`]: reset field names to default.

ROI style

Change ROI colour and transparency for a better visualization of temporary ROIs on the map.

- [`Change colour`] [Q]: change ROI colour;
- [`Reset ROI style`]: reset ROI colour and transparency to default;
- [- `Transparency` -] [Q]: change ROI transparency.

Spectral signature

- < `Plot legend Max number of characters` >: limit the text length of names in the *Plot Signature list* (page 136) legend.

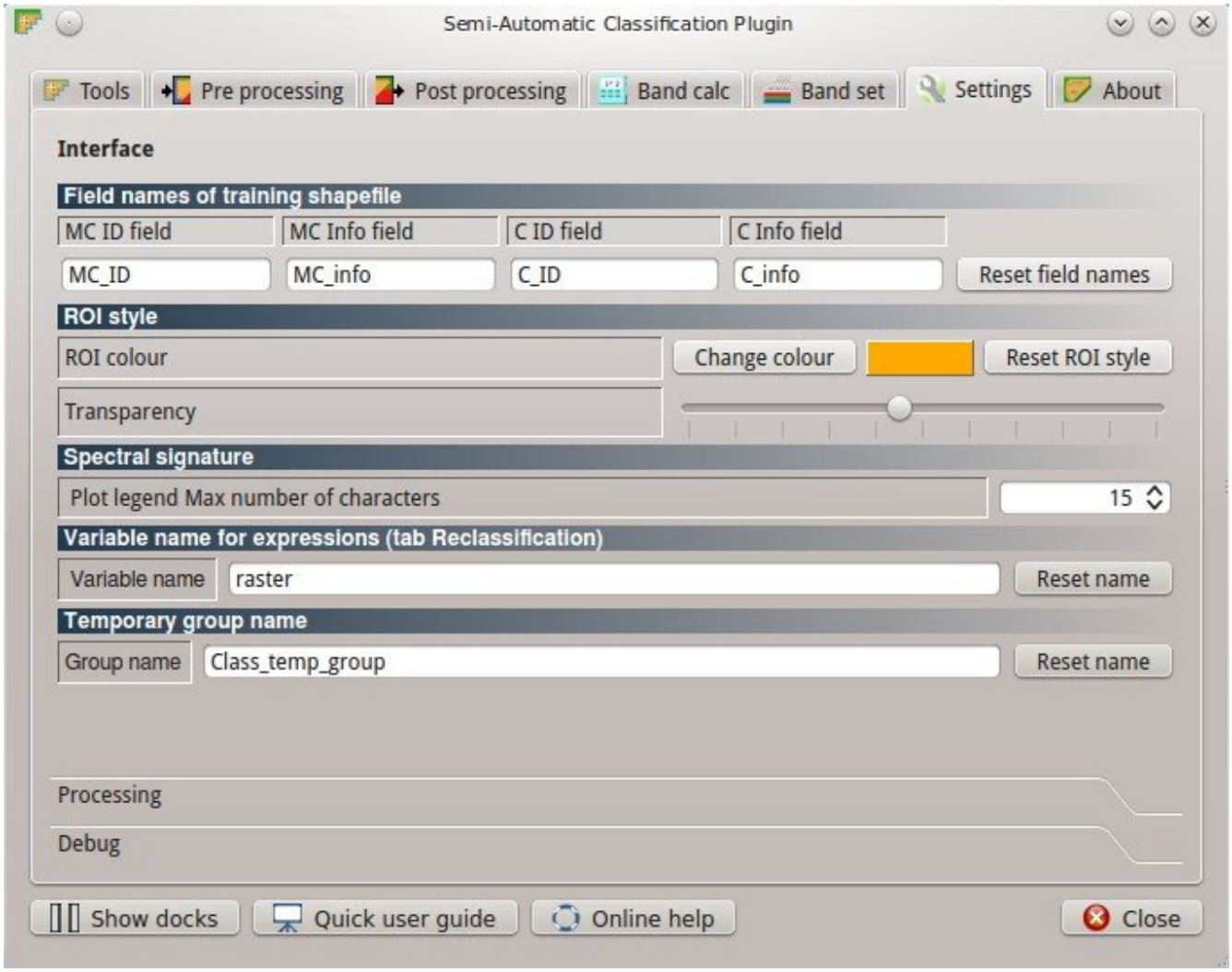


Fig. 17.18: *Settings: Interface*

Variable name for expressions (tab Reclassification)

Set the variable name used in `Old value` expressions of the *Reclassification* (page 124) .

- `Variable name` [Q]: set variable name (default is `raster`);
- [`Reset name`]: reset variable name to default.

Temporary group name

Set the temporary group name in QGIS Layers used for *Classification preview* (page 98) .

- `Group name` [Q]: set group name (default is `Class_temp_group`);
- [`Reset name`]: reset group name to default.

17.6.2 Settings: Processing

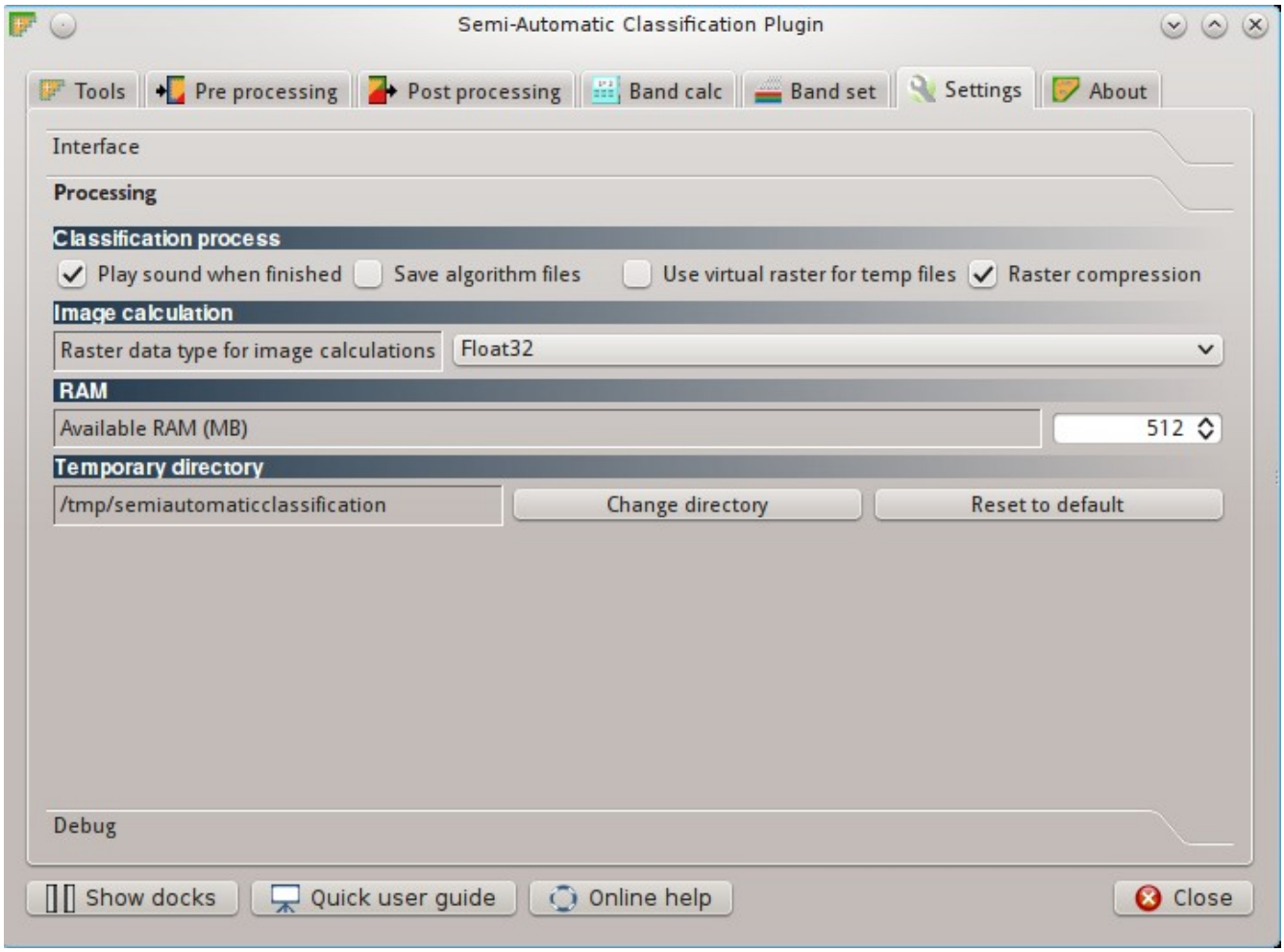


Fig. 17.19: *Settings: Processing*

Classification process

- `Play sound when finished` [Q]: if checked, play a sound when the classification process is completed;

- `Save algorithm files` [Q]: if checked, in addition to the classification output, save the intermediate files calculated by the classification algorithm (one .tif file for each land cover class representing the *similarity* of each pixel to the class thereof);
- `Use virtual rasters for temp files` [Q]: if checked, create virtual rasters for certain temporary files, instead of creating real rasters; it is useful for reducing disk space usage during calculations;
- `Raster compression` [Q]: if checked, a lossless compression (DEFLATE OR PACKBITS) is applied to raster outputs in order to save disk space; however, using raster compression sometimes can produce files larger than rasters without compression.

Image calculation

- `Raster data type for image calculations` [Q]: select the raster data type between Float32 (default) and Float64, which is used for the creation of raster outputs;

RAM

- < `Available RAM (MB)` > [Q]: set the available RAM (in MB) that will be used during the processes; this value should be half of the system RAM (e.g. 1024MB if system has 2GB of RAM);

Temporary directory

- `temporary directory` [Q]: path to the temporary directory;
- [`Change directory`]: select a new temporary directory where temporary files are saved during processing;
- [`Reset to default`]: reset to system default temporary directory.

17.6.3 Settings: Debug

Debugging utilities for the creation of a Log file (i.e. recording of SCP activities for reporting issues) and testing SCP dependencies.

If you found a plugin error, please read *How can I report an error?* (page 207) .

Log file

- `Records events in a log file` [Q]: start recording events in a Log file;
- [`Export Log file`]: open a window for choosing where to save the Log file (i.e. a .txt file);
- [`Clear Log file content`]: clear the content of Log file.

Test

- [`Test dependencies`]: test SCP dependencies (GDAL, GDAL subprocess, NumPy, SciPy, Matplotlib, Internet connection); a window displays the test results.

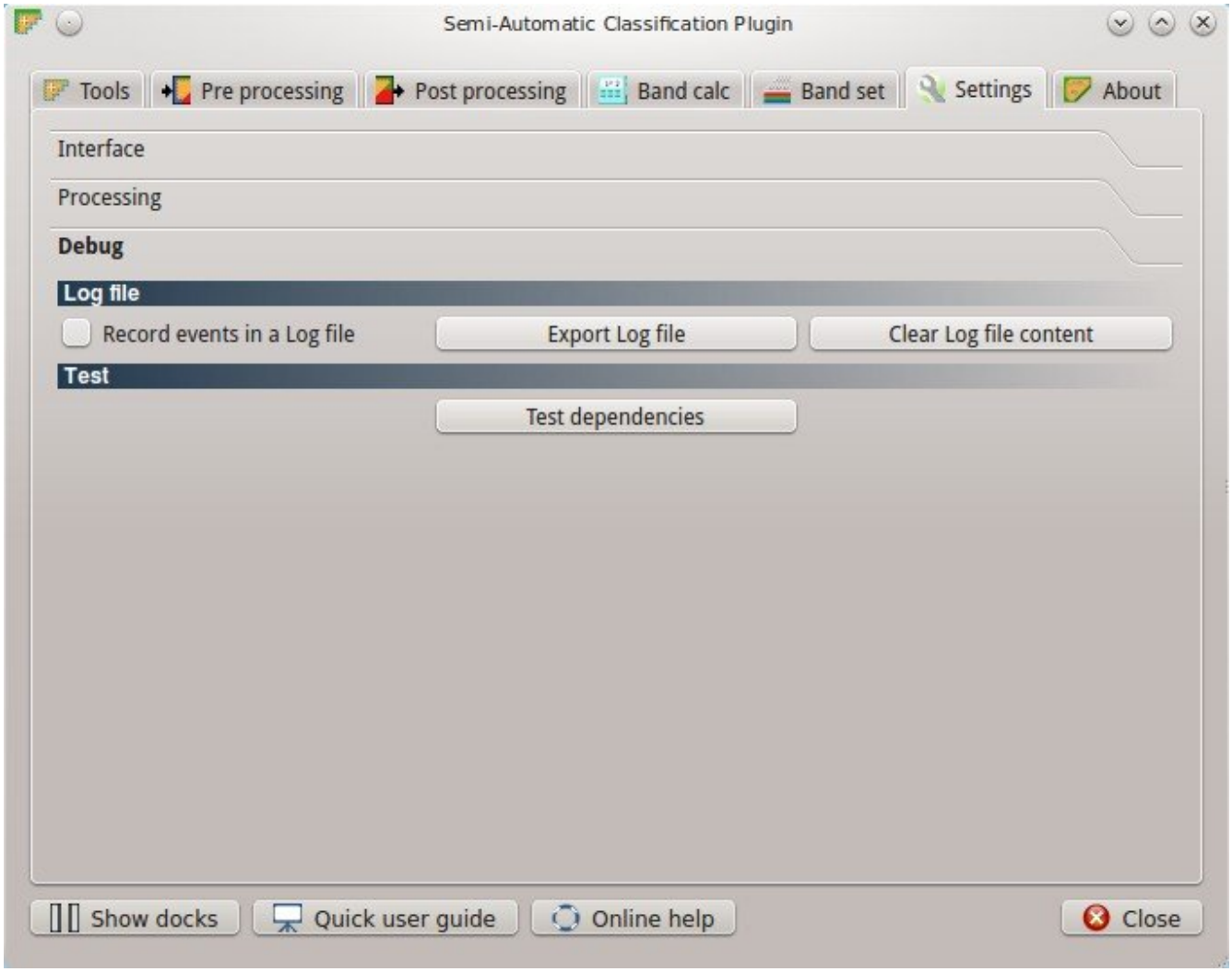


Fig. 17.20: *Settings: Debug*

CHAPTER 18

Spectral Signature Plot

The `Spectral Signature Plot` window allows for the displaying of spectral signature plots, which are the signature values (usually reflectance) as a function of wavelength. Signatures can be added to the `Spectral Signature Plot` through the *ROI Creation dock* (page 89) and the *Classification dock* (page 95). Only signatures checked in the *Plot Signature list* (page 136) are displayed (which is independent from *Signature list* (page 95) in the *Classification dock* (page 95)).

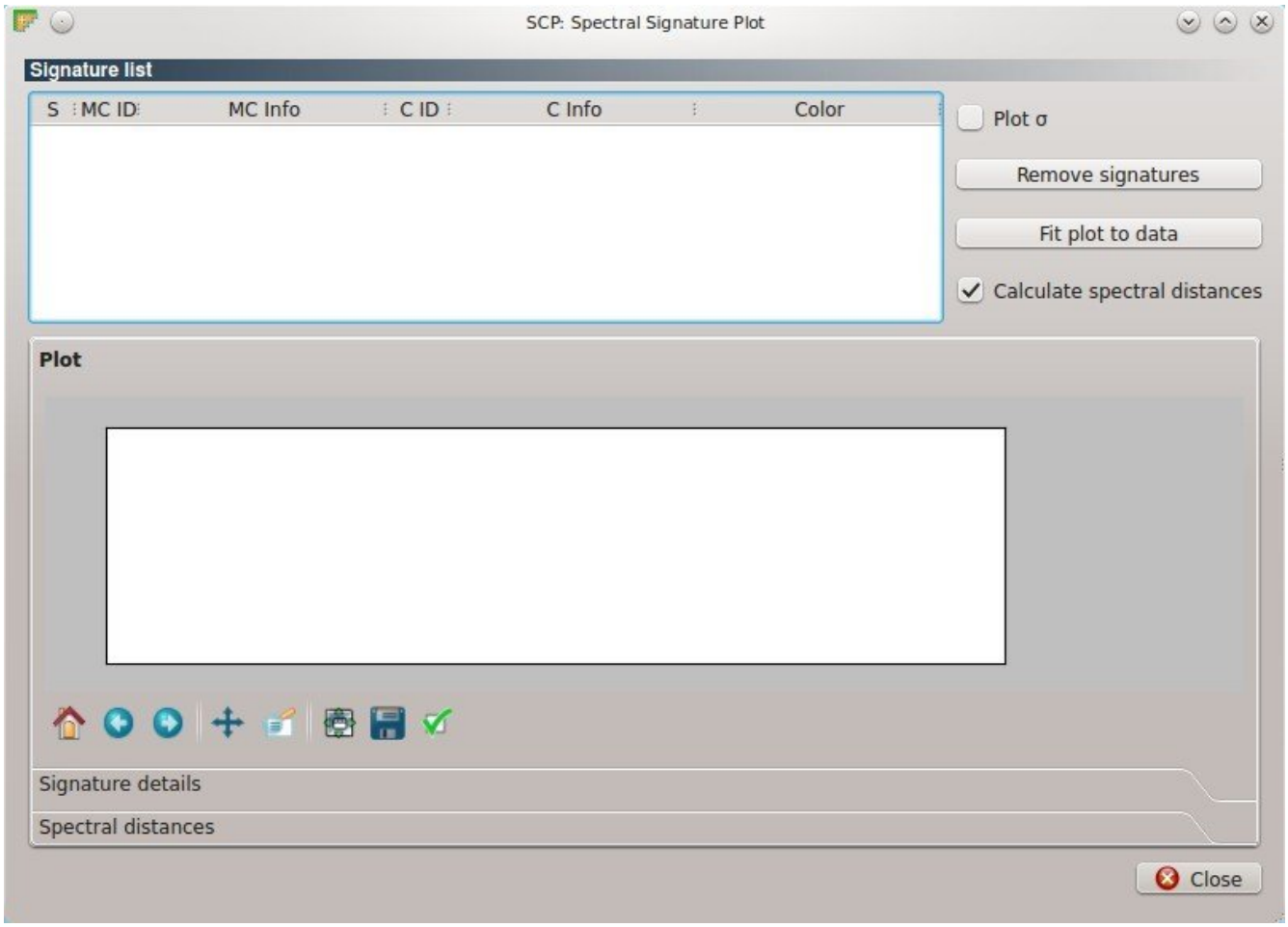


Fig. 18.1: *Spectral Signature Plot*

The following video shows this tool.

http://www.youtube.com/watch?t=900&v=acxmIrM-Qns

Alternative video link https://archive.org/details/video_tutorial_Landsat_mosaic_ENG?start=900

18.1 Plot Signature list

- **Table fields:**
  - `S` : checkbox field; if checked, then signature is displayed in the plot;
  - `MC ID` : Macroclass ID;
  - `MC Info` : Macroclass Information;
  - `Class ID` : Class ID;
  - `C Info` : Class Information;
  - `Color` : color field; double click to select a color for the plot;
- `Plot` σ : if checked, plot the standard deviation for each signature;
- [`Remove signatures`]: remove highlighted signatures from this list;
- [`Fit to data`]: resize the plot to fit to all the data;
- **`Calculate spectral distances`** [if checked, calculate the following spectral distances:]
  - *Jeffries-Matusita Distance* (page 42);
  - *Spectral Angle* (page 43);
  - *Euclidean Distance* (page 43);
  - *Bray-Curtis Similarity* (page 43).

18.1.1 Plot

It is possible to move the legend inside the plot with the mouse.

- **Plot commands (from Matplotlib):**
  - : Reset to original view;
  - : Back to previous view;
  - : Forward to next view;
  - : Pan axes with left mouse, zoom with right;
  - : Zoom to rectangle;
  - : Unused;
  - : Save plot to a figure (e.g. JPG file);
  - : Unused.

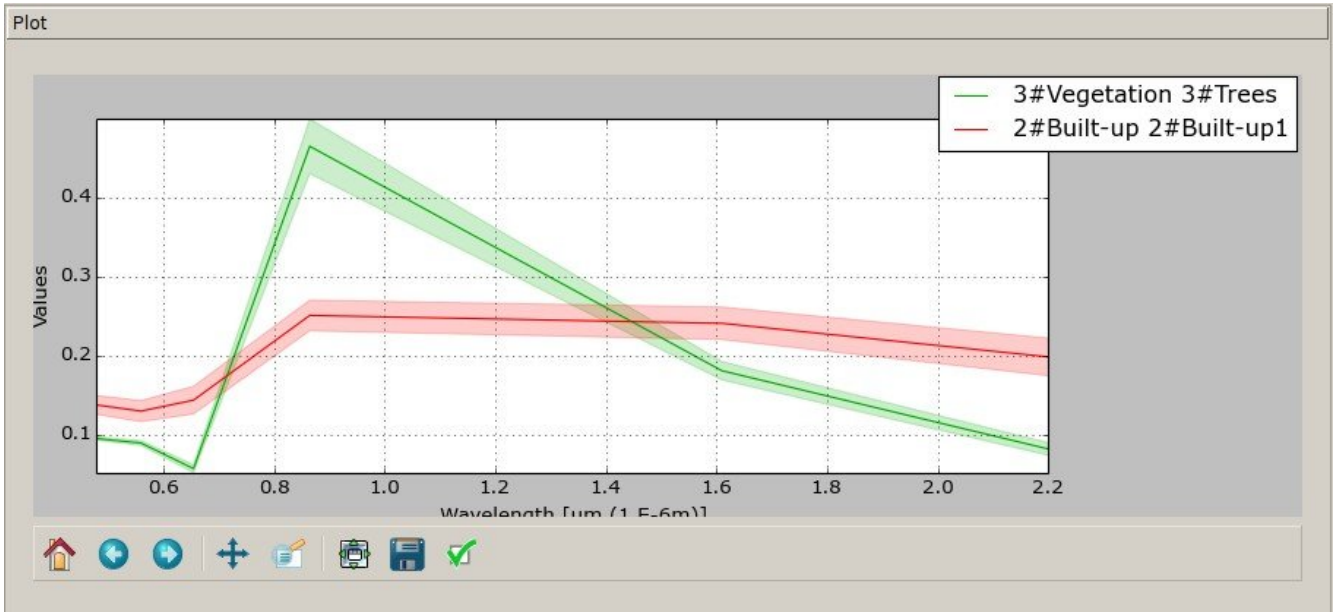


Fig. 18.2: *Spectral Signature: Example of spectral signature plot*

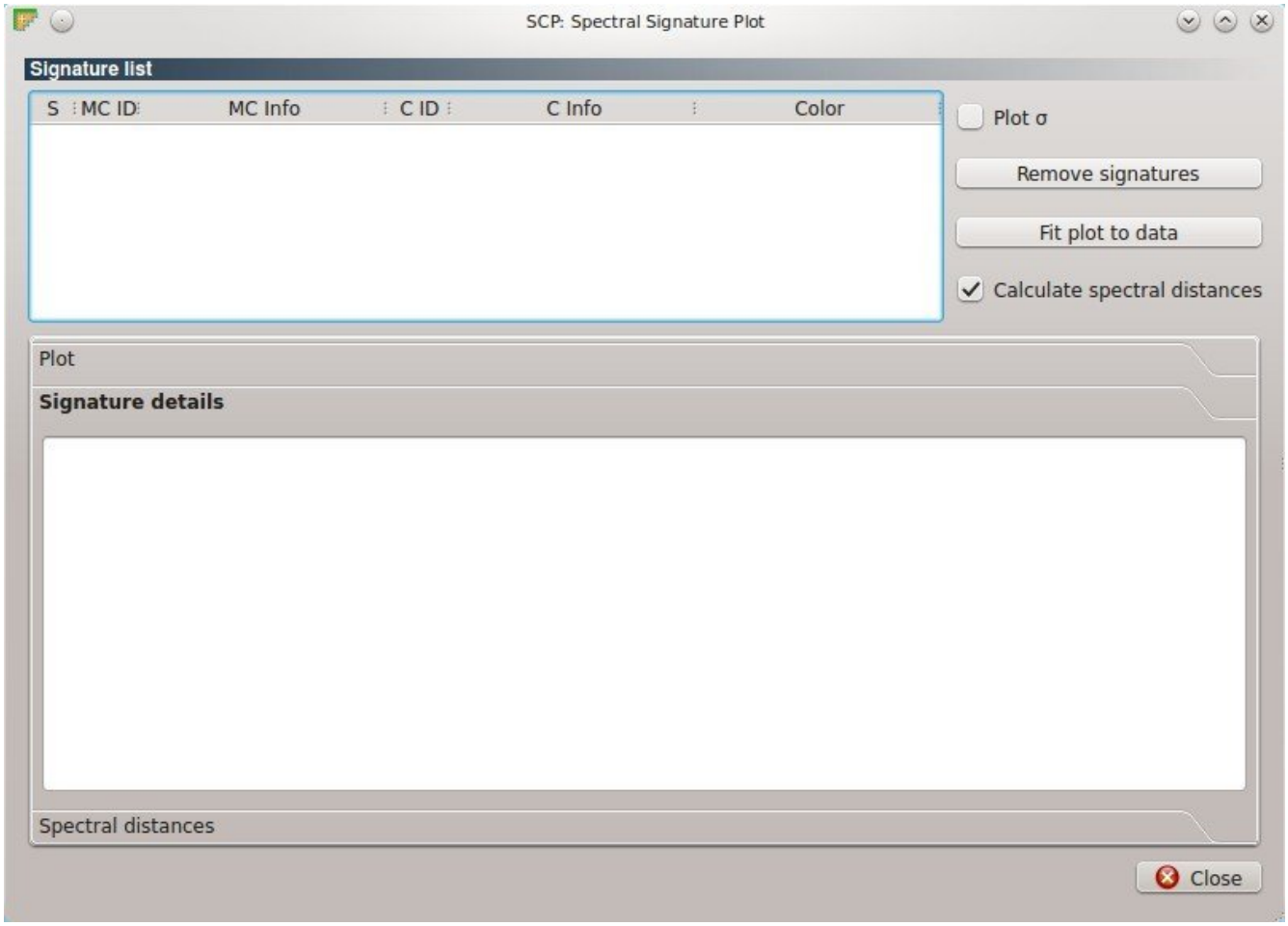


Fig. 18.3: *Spectral Signature: Signature details*

18.1.2 Signature details

Display the details about spectral signatures (i.e. Wavelength, Values, and Standard deviation).

This is useful for comparing the values of different spectral signatures or pixels.

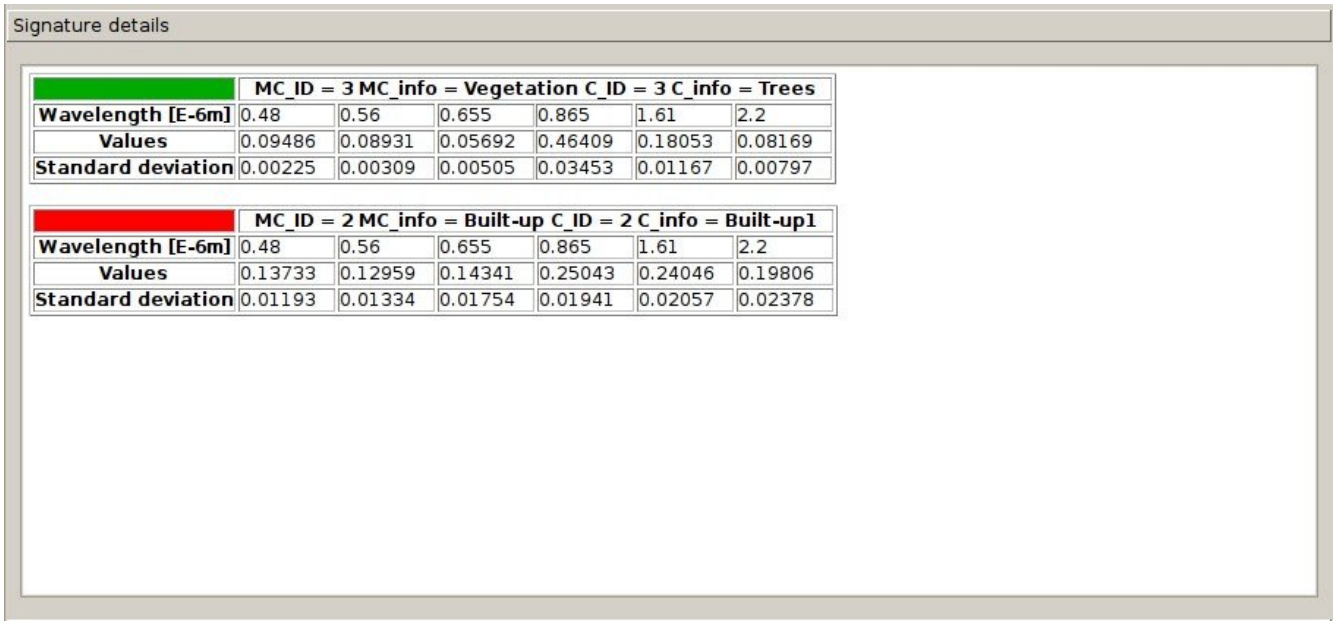


Fig. 18.4: *Spectral Signature: Example of signature details*

18.1.3 Spectral distances

Display spectral distances for each combination of signatures, if `Calculate spectral distances` is checked in *Plot Signature list* (page 136) . It is useful for assessing ROI separability (see *Spectral Distance* (page 42)).

The following spectral distances are calculated :

- Jeffries-Matusita distance: range [0 = identical, 2 = different]; useful in particular for *Maximum Likelihood* (page 41) classifications;
- Spectral angle: range [0 = identical, 90 = different]; useful in particular for *Spectra Angle Mapping* (page 42) classifications;
- Euclidean distance: useful in particular for *Minimum Distance* (page 40) classifications;
- Bray-Curtis similarity [%]: range [0 = different, 100 = identical]; useful in general.

Values are displayed in red if signatures are particularly similar.

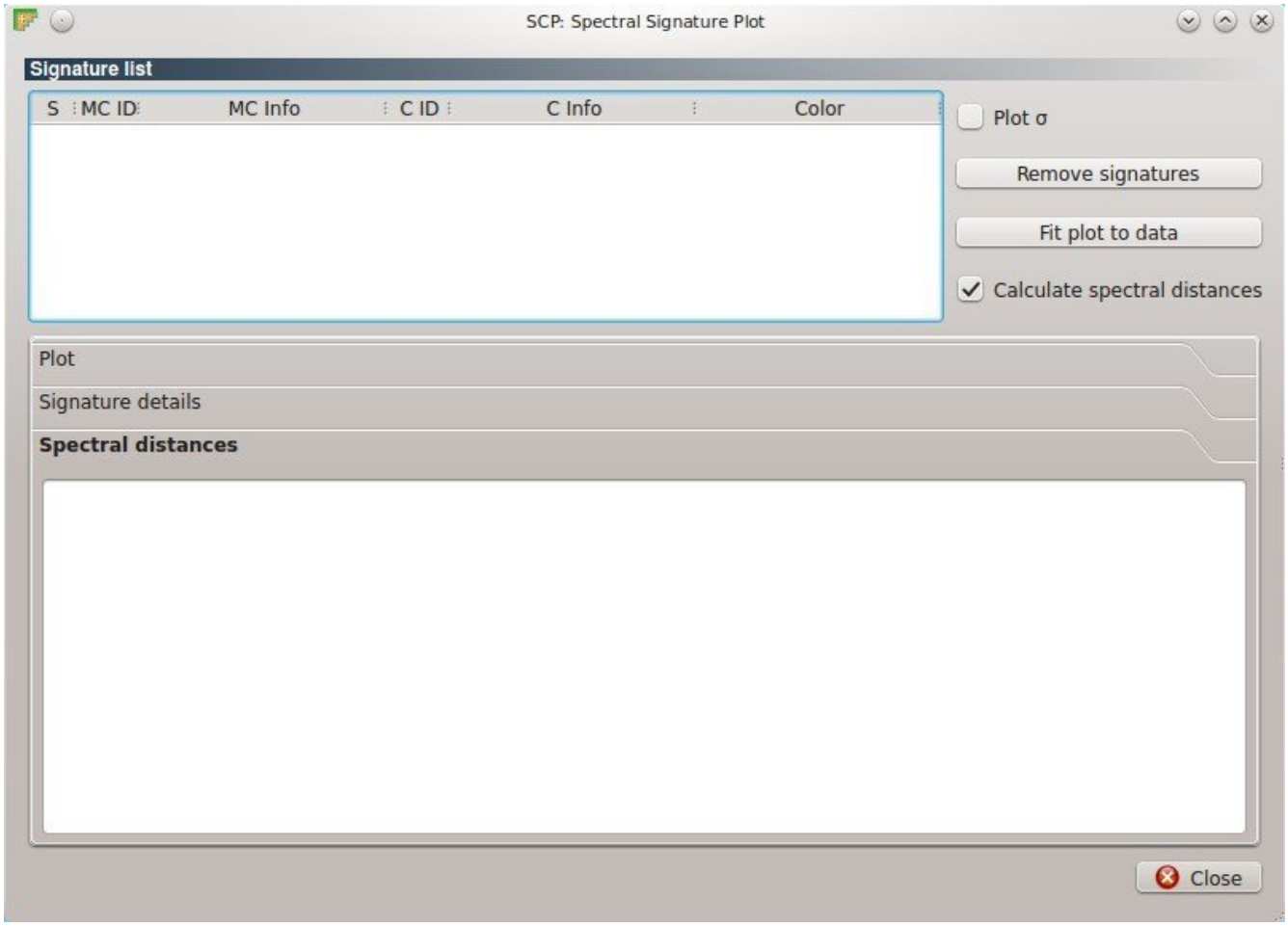


Fig. 18.5: *Spectral Signature: Spectral distances*

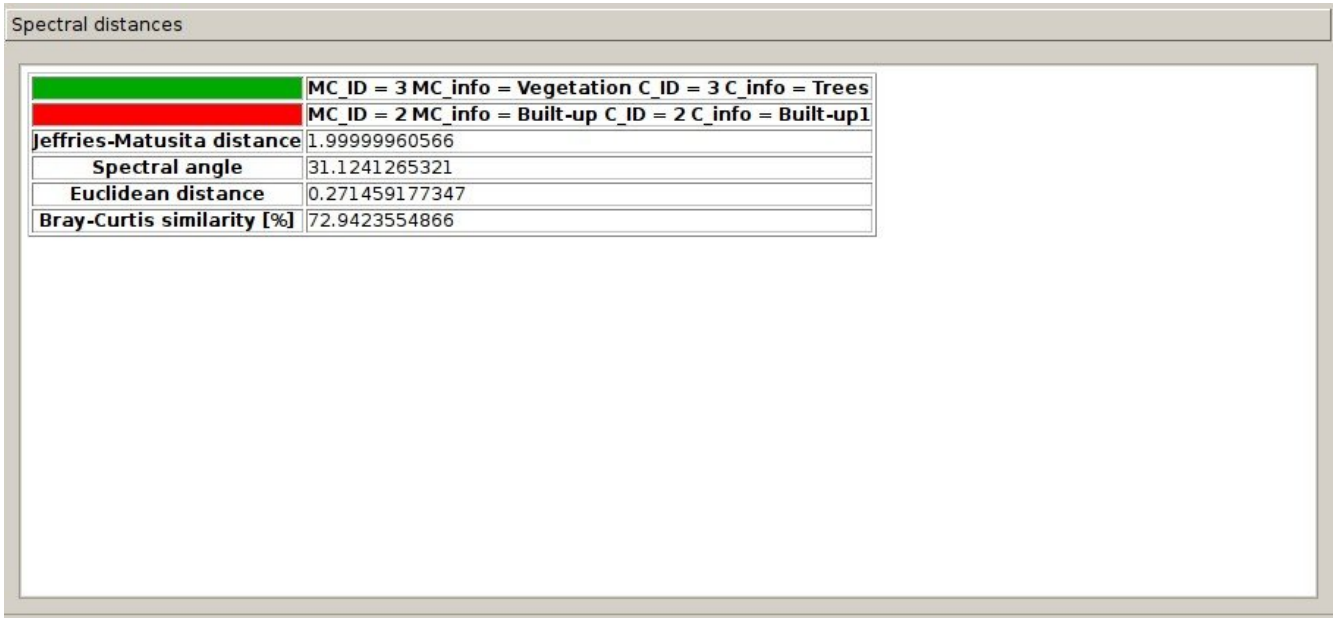

Spectral distances
MC_ID = 3 MC_info = Vegetation C_ID = 3 C_info = Trees
MC_ID = 2 MC_info = Built-up C_ID = 2 C_info = Built-up1
Jeffries-Matusita distance 1.99999960566
Spectral angle 31.1241265321
Euclidean distance 0.271459177347
Bray-Curtis similarity [%] 72.9423554866

Fig. 18.6: *Spectral Signature: Example of spectral distances*

Scatter Plot

The `Scatter plot` window allows for the calculation of the ROI scatter plots, which are useful for assessing ROI separability between two bands. Pixel values for two raster bands are represented as points in the 2D space.

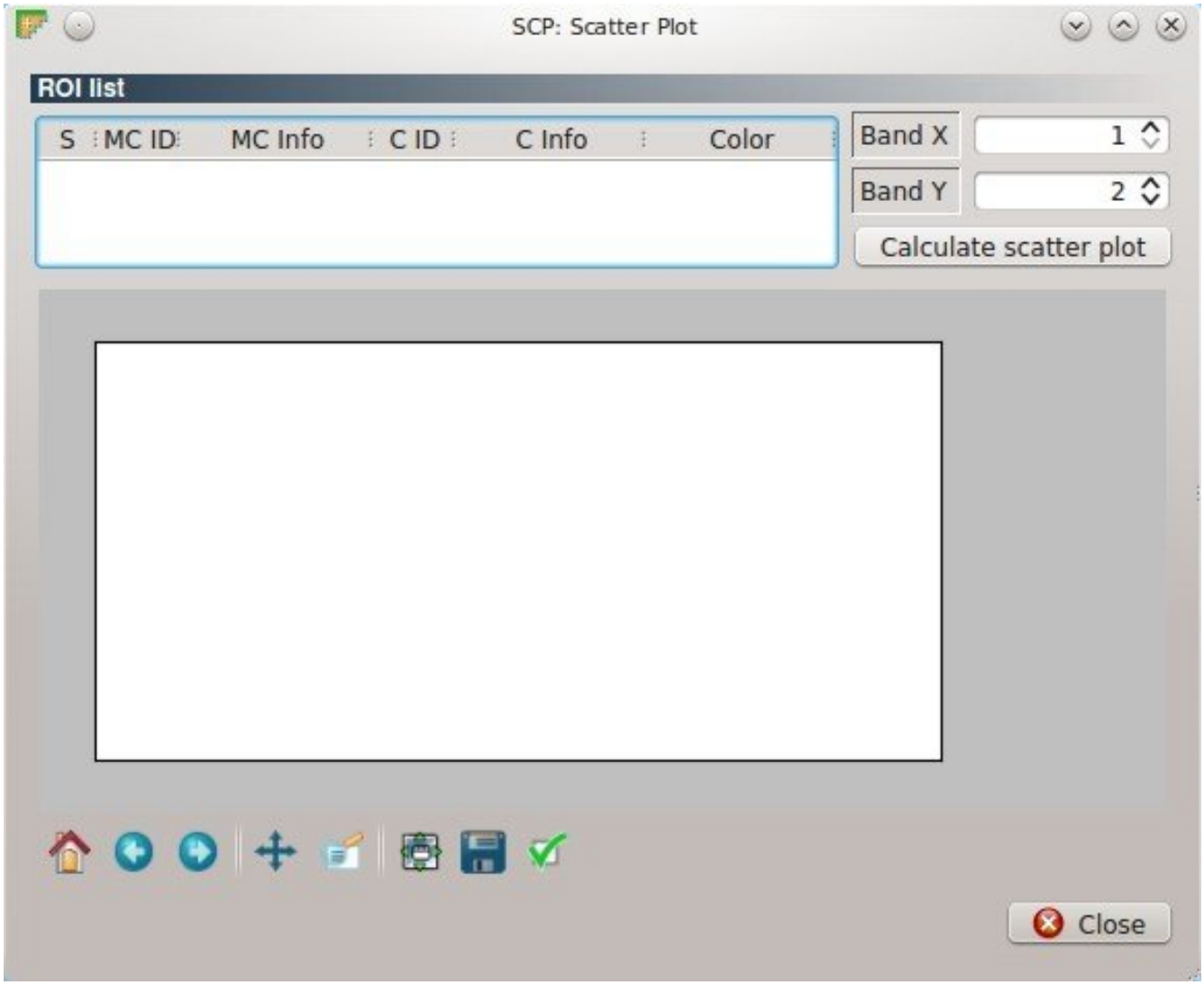


Fig. 19.1: *Scatter Plot*

19.1 ROI List

- **Table fields:**
  - `S` : checkbox field;
  - `MC ID` : Macroclass ID;
  - `MC Info` : Macroclass Information;
  - `C ID` : Class ID;
  - `C Info` : Class Information;
  - `Color` : color field; double click to select a color for the plot;
- < `Band X` >: X band of the plot;
- < `Band Y` >: Y band of the plot;
- [`Calculate scatter plot`]: calculate the scatter plot for the ROI checked in the list (it can be time consuming).
- **Plot commands (from Matplotlib):**
  - : Reset to original view;
  - : Back to previous view;
  - : Forward to next view;
  - : Pan axes with left mouse, zoom with right;
  - : Zoom to rectangle;
  - : Unused;
  - : Save plot to a figure (e.g. JPG file);
  - : Unused.

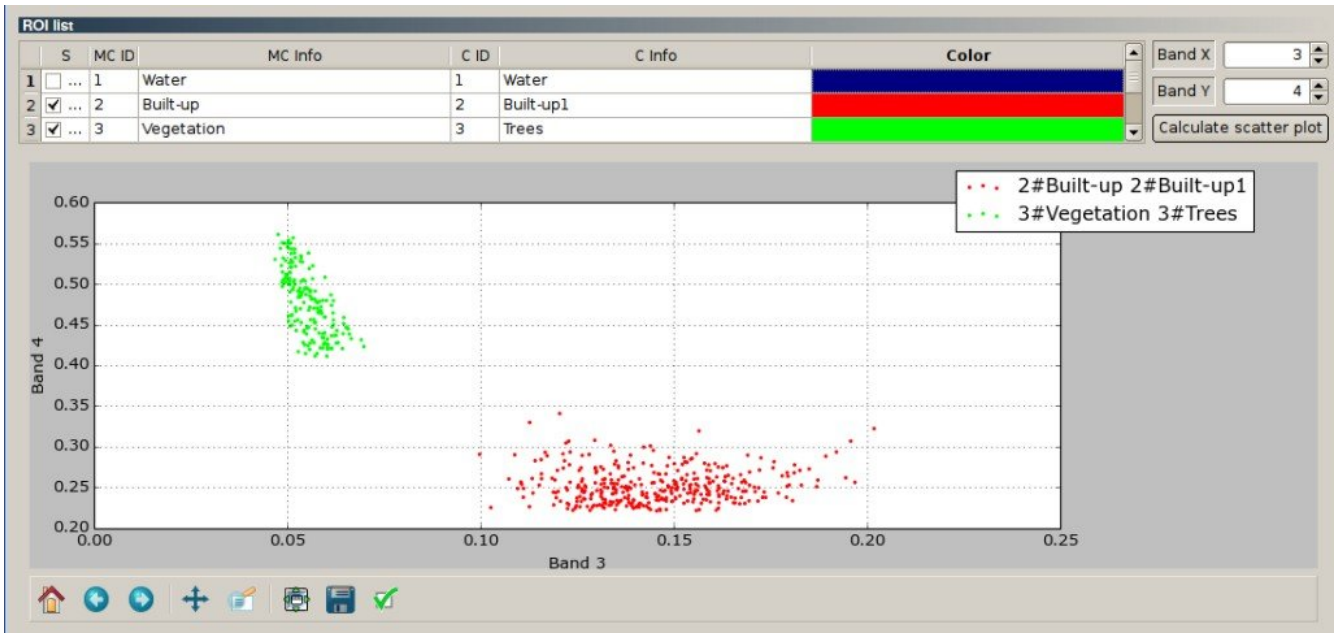


Fig. 19.2: *Example Scatter Plot*

Part V

Thematic Tutorials

The following are thematic tutorials. Before these tutorials, it is recommended to read the *Basic Tutorials* (page 55).

- *Tutorial: Land Cover Classification and Mosaic of Several Landsat images* (page 149)
  - *Plugin installation* (page 149)
  - *Download and Pre processing of Landsat images* (page 150)
  - *Classification of Landsat Images* (page 155)
  - *Enhancement of Classification Using NDVI* (page 167)
  - *Cloud Masking* (page 170)
  - *Mosaic of Classifications* (page 173)
  - *Accuracy Assessment* (page 173)
  - *Clip of the Classification* (page 174)
  - *Classification Report* (page 175)
- *Tutorial: Using the tool Band calc* (page 179)
  - *Application of a mask to multiple bands* (page 179)
  - *NDVI Calculation* (page 181)
  - *Classification refinement basing on NDVI values* (page 183)
- *Other Tutorials* (page 187)

CHAPTER 20

Tutorial: Land Cover Classification and Mosaic of Several Landsat images

This tutorial is about the land cover classification of several Landsat images in order to create a classification of a large study area using the Semi-Automatic Classification Plugin (SCP). For very basic tutorials see *Tutorial 1: Your First Land Cover Classification* (page 57) and *Tutorial 2: Land Cover Classification of Landsat Images* (page 65).

The study area of this tutorial is Costa Rica , a Country in Central America that has an extension of about 51,000 square kilometres. In particular, we are going to classify Landsat 8 and Landsat 7 images, masking clouds and creating a mosaic of classifications. We are going to identify the following land cover classes:

1. Built-up;
2. Vegetation;
3. Soil;
4. Water.

Following the video of this tutorial.

http://www.youtube.com/watch?v=acxmIrM-Qns

Alternative video link https://archive.org/details/video_tutorial_Landsat_mosaic_ENG

20.1 Plugin installation

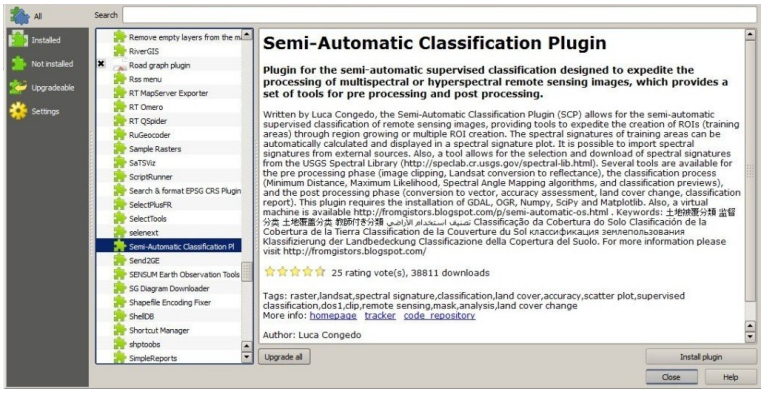
First, install the SCP. For information about the installation of QGIS in various systems see *Plugin Installation* (page 5).

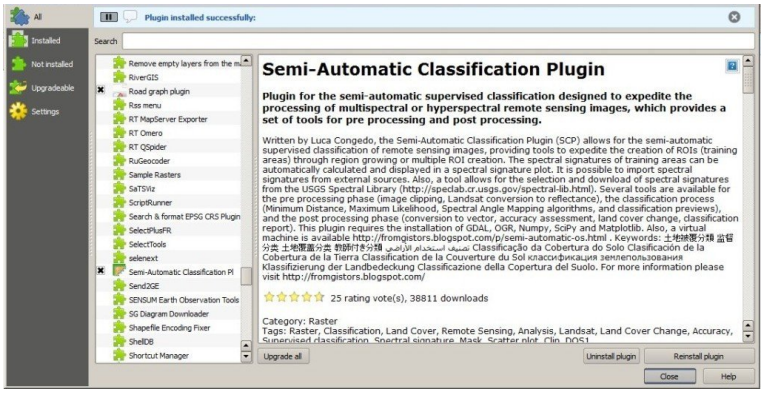
Open QGIS; from the main menu, select `Plugins` > `Manage and Install Plugins`;

From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;

The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);

We are going to set some of the SCP options in order to optimize the following processes. Open the *Settings* (page 129) clicking the button and select *Settings: Processing* (page 131). Now, in *Classification process* (page 131) check the options `Use virtual rasters for temp files` and `Raster compression`, in order to save disk space during the processing.


Semi-Automatic Classification Plugin
Plugin for the semi-automatic supervised classification designed to expedite the processing of multispectral or hyperspectral remote sensing images, which provides a set of tools for pre processing and post processing.
Written by Luca Congedo, the Semi-Automatic Classification Plugin (SCP) allows for the semi-automatic supervised classification of remote sensing images, providing tools to expedite the creation of ROIs (training areas) through region growing or multiple ROI creation. The spectral signatures of training areas can be automatically calculated and displayed in a spectral signature plot. It is possible to import spectral signatures from external sources. Also, a tool allows for the selection and download of spectral signatures from the USGS Spectral Library (http://speclab.cr.usgs.gov/spectral-lib.html). Several tools are available for the pre processing phase (image clipping, Landsat conversion to reflectance), the classification process (Minimum Distance, Maximum Likelihood, Spectral Angle Mapping algorithms, and classification previews), and the post processing phase (conversion to vector, accuracy assessment, land cover change, classification report). This plugin requires the installation of GDAL, OGR, Numpy, SciPy and Matplotlib. Also, a virtual machine is available http://fromgistors.blogspot.com/p/semi-automatic-os.html . Keywords:
Classificação da Cobertura do Solo Clasificación de la Cobertura de la Tierra Classification de la Couverture du Sol классификация землепользования Klassifizierung der Landbedeckung Classificazione della Copertura del Suolo. For more information please visit http://fromgistors.blogspot.com/
25 rating vote(s), 38811 downloads
Tags: raster,landsat,spectral signature,classification,land cover,accuracy,scatter plot,supervised classification,dos1,clip,remote sensing,mask,analysis,land cover change
More info: homepage tracker code repository
Author: Luca Congedo
Upgrade all
Install plugin
Close
Help


Plugin installed successfully:
Semi-Automatic Classification Plugin
Plugin for the semi-automatic supervised classification designed to expedite the processing of multispectral or hyperspectral remote sensing images, which provides a set of tools for pre processing and post processing.
25 rating vote(s), 38811 downloads
Category: Raster
Upgrade all
Uninstall plugin
Reinstall plugin
Close
Help

In *RAM* (page 132) set the available RAM (in MB) for processing entering half of the system RAM; for instance it your system has 2GB of RAM enter 1024. If the system is 32bit, due to system limitations you should not enter values higher than 512MB.

In order to ease the photo interpretation in the following steps, we are going to use also the OpenLayers Plugin which allows for the display of several maps. If you don't have already installed, follow the same steps previously described and install the OpenLayers Plugin in QGIS.

20.2 Download and Pre processing of Landsat images

We are going to **download Landsat 7 and 8 images** using the SCP tool *Download Landsat* (page 108). Landsat images are available from the U.S. Geological Survey, and these bands are downloaded through the Google Earth Engine and the Amazon Web Services. Also, we are going to convert Landsat images to **reflectance** and apply the DOS1 atmospheric correction (see *Landsat image conversion to reflectance and DOS1 atmospheric correction* (page 47)).

First, we need to download the Landsat database in SCP. Open the tab *Download Landsat* (page 108) clicking the button in the *SCP menu* (page 85) or the *Toolbar* (page 87). Click the button `Select database directory` in order to define where to save the database. It is preferable to create a new directory (e.g. `LandsatDB`) in the user directory. Click the button `Update database` and click `Yes` in the following question about updating the image database.

> **TIP** : Landsat databases are updated daily, therefore when you need up to date images you should click the button `Update database` in order to the get the latest Landsat images.

Now we could define the *Area coordinates* (page 110) of the study area, click `Find images` and browse Landsat images. Each Landsat image has a unique ID (i.e. identifier). In this tutorial we are going to use two Landsat 8 images acquired on February 2014 (IDs: LC80150532014050LGN00 and LC80160532014057LGN00) and a Landsat 7 image acquired on March 2014 (ID: LE70150532014090EDC00); of course, more images are required for the classification of the whole Country.

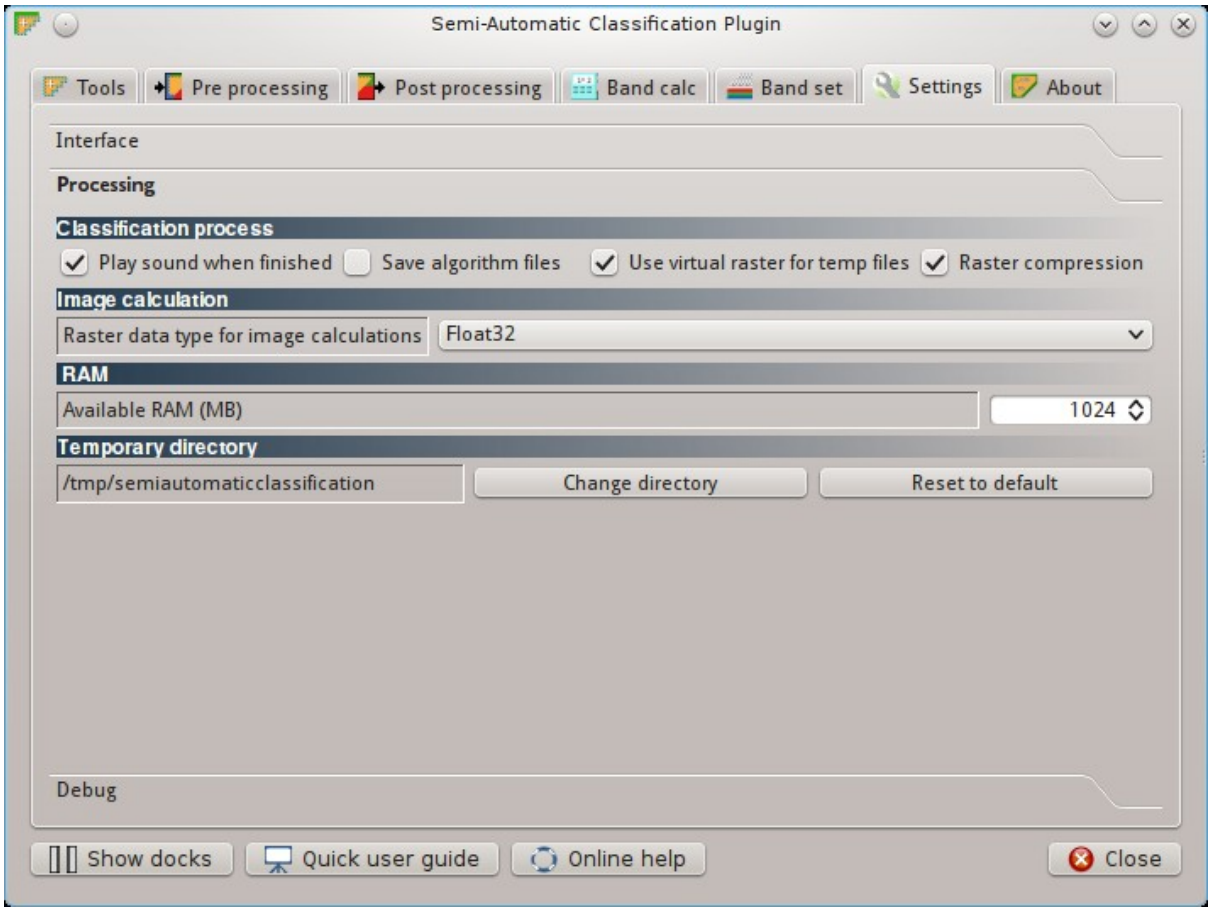


Fig. 20.1: *SCP settings*

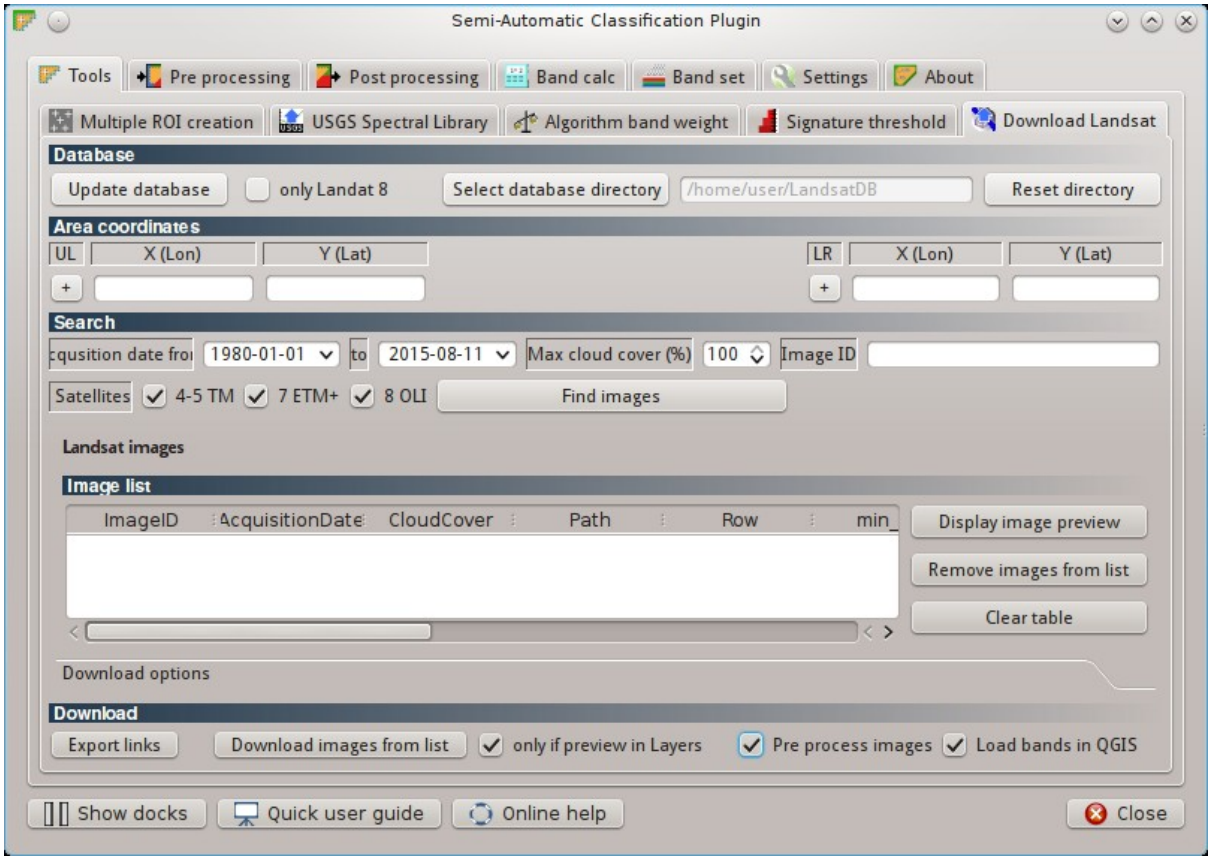


Fig. 20.2: *Landsat database download*

With SCP, it is possible to find an image basing on the ID thereof using the *Search* (page 110) options. In particular, in `Image ID` paste the following IDs and click `Find images`:

```
LC80150532014050LGN00; LC80160532014057LGN00; LE70150532014090EDC00
```

After a few seconds, the three images are listed in the *Landsat images* (page 110).

Before downloading the images, we need to define the options for the conversion to reflectance which will be performed automatically to downloaded images. Open the tab *Landsat* (page 114) clicking the button in the *Toolbar* (page 87) ; enable the options `Apply DOS1 atmospheric correction` and `Brightness temperature in Celsius`. Also, leave checked `Use NoData value (image has black border)`.

> **TIP** : check `Perform pan-sharpening` in order to perform the *Pan-sharpening* (page 35) of Landsat images producing bands with 15m spatial resolution; of course, using pan-sharpened images increases the classification time (because a greater number of pixels need to be processed) and can increase the spectral variability.

Now, open the tab *Download Landsat* (page 108) and uncheck the options `only if preview in Layers` and `Load bands in QGIS` (leave checked `Pre process images` in order to convert bands to reflectance automatically). Click the button `Download images from list` to select an output directory and start the download process (this may take a while).

When the download process is finished, several directories are created in the output directory with the name like Landsat ID, containing the original Landsat bands and the converted bands (with the suffix `_converted`).

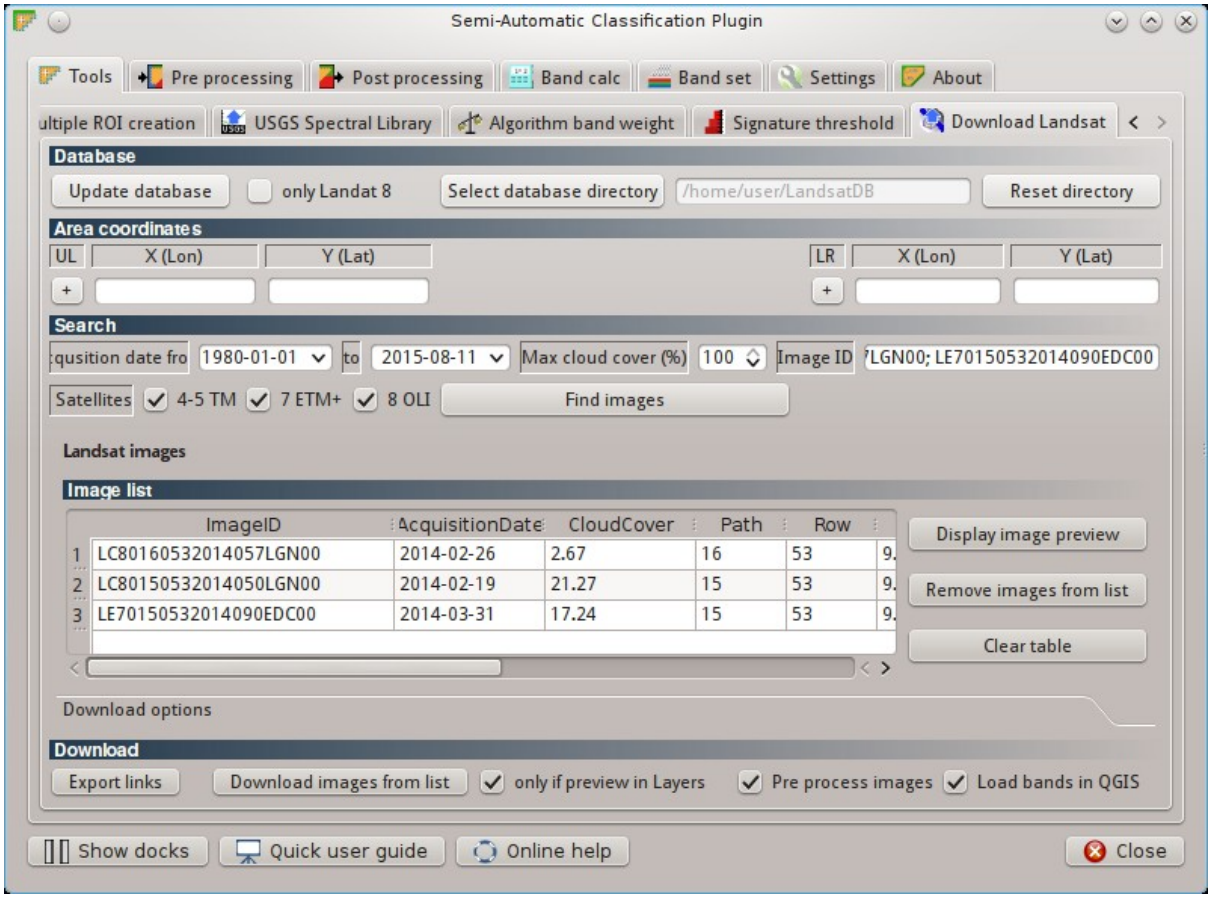


Fig. 20.3: *Landsat image search*

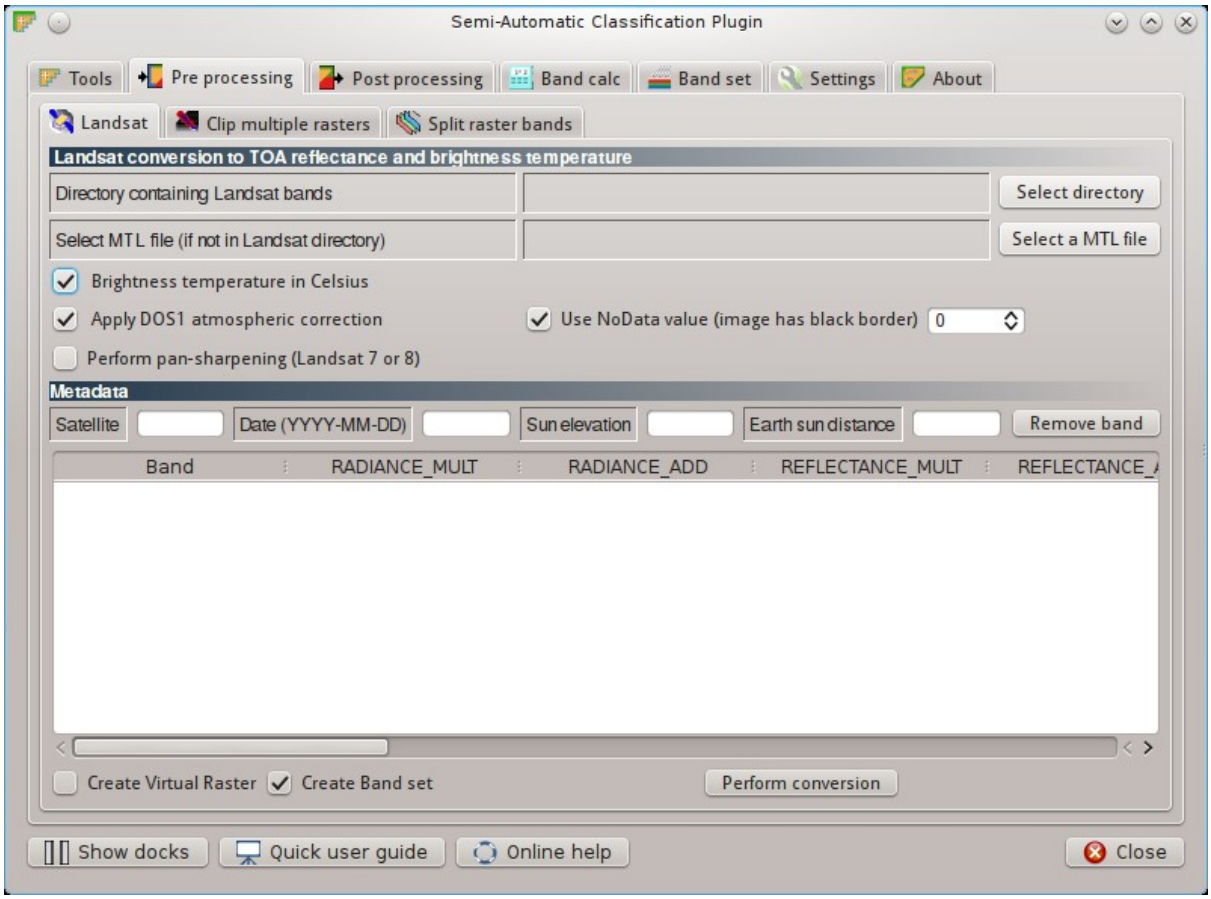


Fig. 20.4: *Landsat pre processing*

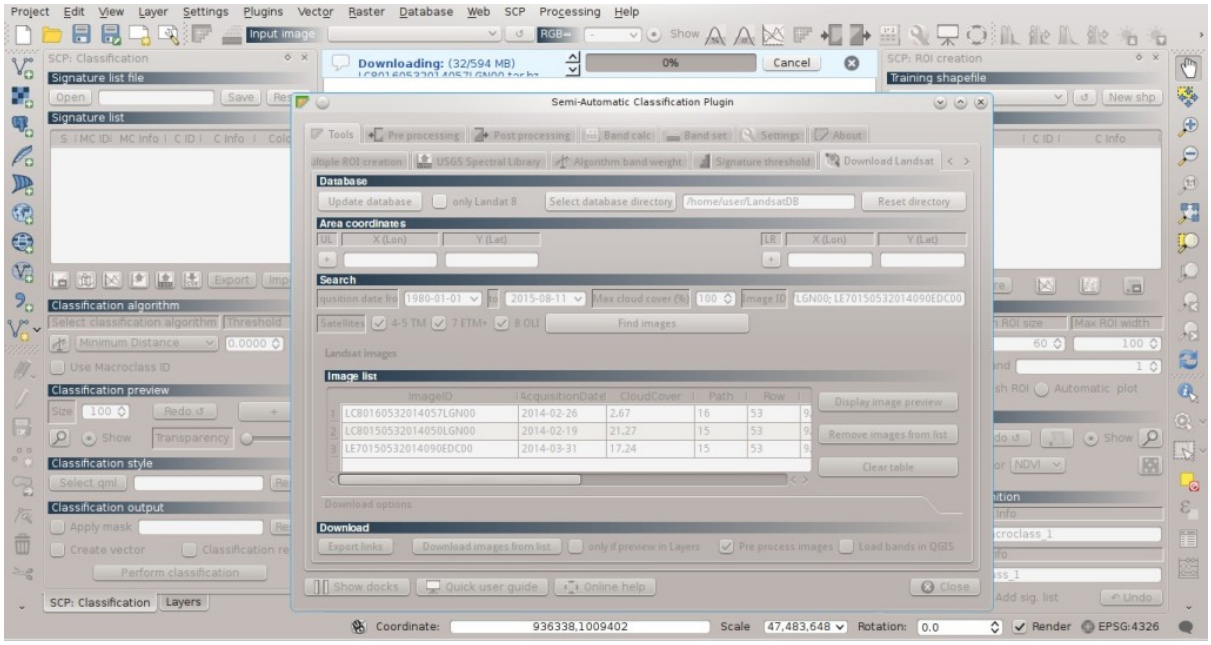


Fig. 20.5: *Landsat download*

20.3 Classification of Landsat Images

We are going to start the classification of the Landsat 8 image `LC80150532014050LGN00` converted to reflectance. Open the directory `LC80150532014050LGN00_converted`.

In QGIS, open the following bands (also with drag and drop):

- RT_LC80150532014050LGN00_B2.tif = Blue;
- RT_LC80150532014050LGN00_B3.tif = Green;
- RT_LC80150532014050LGN00_B4.tif = Red;
- RT_LC80150532014050LGN00_B5.tif = Near-Infrared;
- RT_LC80150532014050LGN00_B6.tif = Short Wavelength Infrared 1;
- RT_LC80150532014050LGN00_B7.tif = Short Wavelength Infrared 2.

Open the tab *Band set* (page 127) clicking the button in the *SCP menu* (page 85) or the *Toolbar* (page 87). Click the button `Select All`, then `Add rasters to set`, and then `Sort by name` for ordering bands automatically. Finally, select `Landsat 8 OLI` from the combo box `Quick wavelength settings`, in order to set automatically the center wavelength of each band (this is required for the spectral signature calculation).

> **TIP** : click the button `Build band overviews` in order to improve display performance of bands.

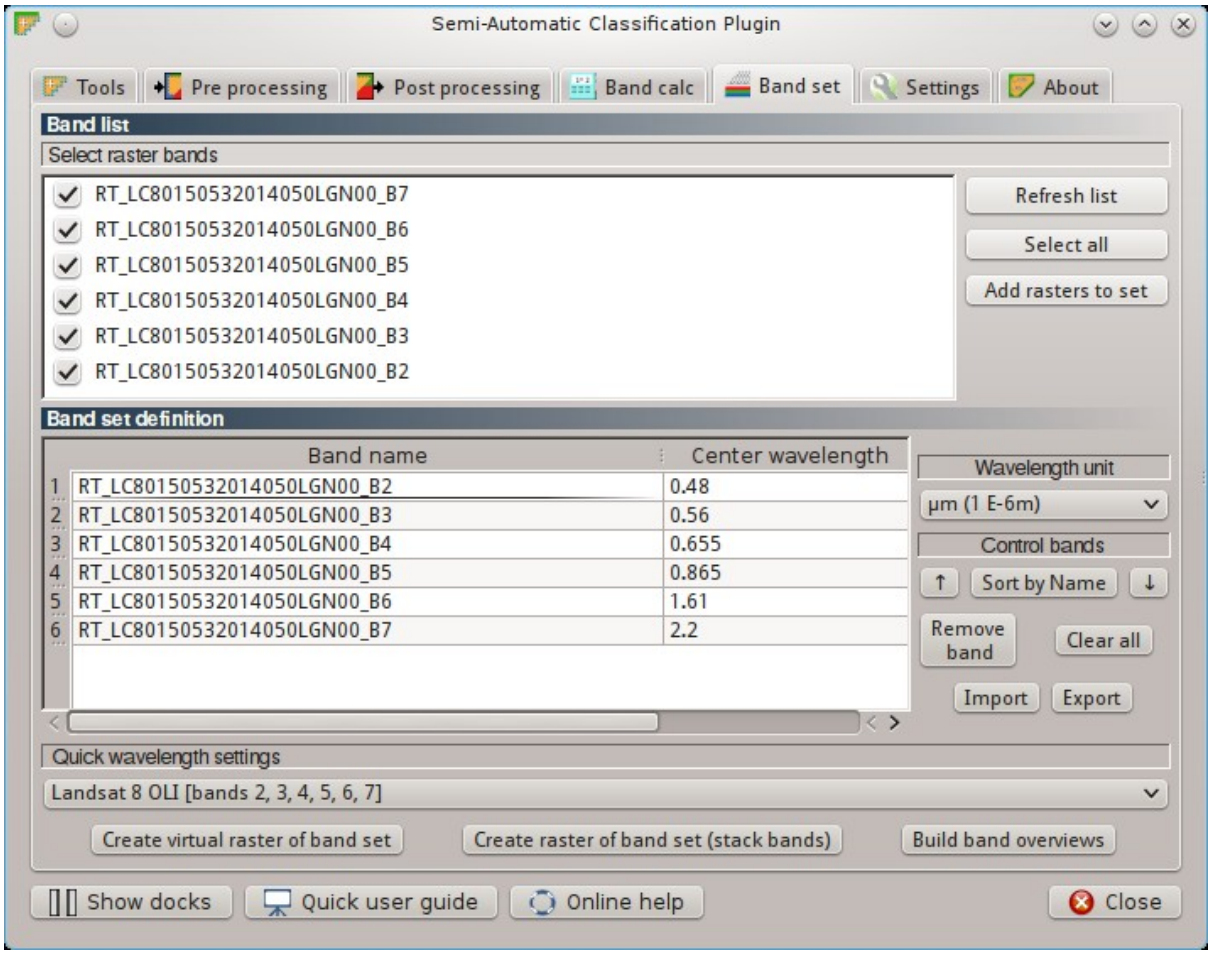


Fig. 20.6: *Definition of Band set*

In the list RGB select the item 4-3-2 for displaying a *Color Composite* (page 35) of Near-Infrared, Red, and Green. A temporary virtual raster of the Band set will be created in QGIS, allowing for the photo interpretation of the image.

Now we need to create Training shapefile and Signature list file in order to collect *Training Areas* (page 39) (ROIs) and calculate the *Spectral Signature* (page 33) thereof (for very basic definitions see *Tutorial 1: Your First Land Cover Classification* (page 57)).

In the *ROI Creation dock* (page 89) click the button New shp and define a name (e.g. ROI.shp) in order to create the Training shapefile that will store ROI polygons. The shapefile is created and added to QGIS. The name of the Training shapefile is displayed in *Training shapefile* (page 89) .

Also, click the button Save in the *Classification dock* (page 95) and define a name (e.g. SIG.xml) in order to create the Signature list file that will store spectral signatures. The path of the Signature list file is displayed in *Signature list file* (page 95) .

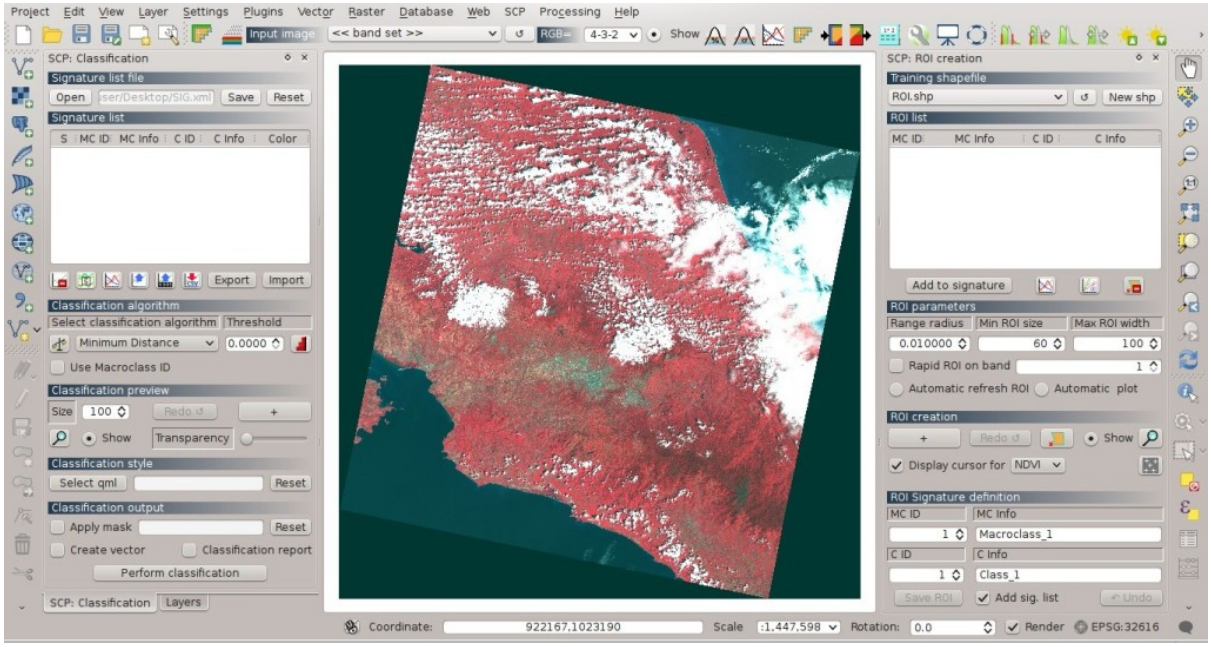


Fig. 20.7: *Definition of SCP input for the Landsat image LC80150532014050LGN00*

Now we are ready for the creation of ROIs. We are going to use the same codes for ROIs in all the Landsat images, according to the following table.

Macroclass name	Macroclass ID
Built-up	1
Vegetation	2
Soil	3
Water	4

About the basics of ROI creation see *Create the ROIs* (page 58). It is possible to create ROIs by drawing manually a polygon using the button or with region growing pressing the button + and then clicking the map. Use the button in *ROI creation* (page 92) for zooming to the polygon extent of the ROI, and Show for showing or hiding the temporary ROI.

With the *ROI Creation dock* (page 89) create as many ROIs as possible, assigning a unique Class ID (C_ID) to each ROI, and the Macroclass ID (MC_ID) of the corresponding Macroclass. If Display cursor for is checked in the *ROI creation* (page 92), the NDVI value of the pixel beneath the cursor is displayed in the map: it is useful for detecting vegetation pixels (characterized by high NDVI values).

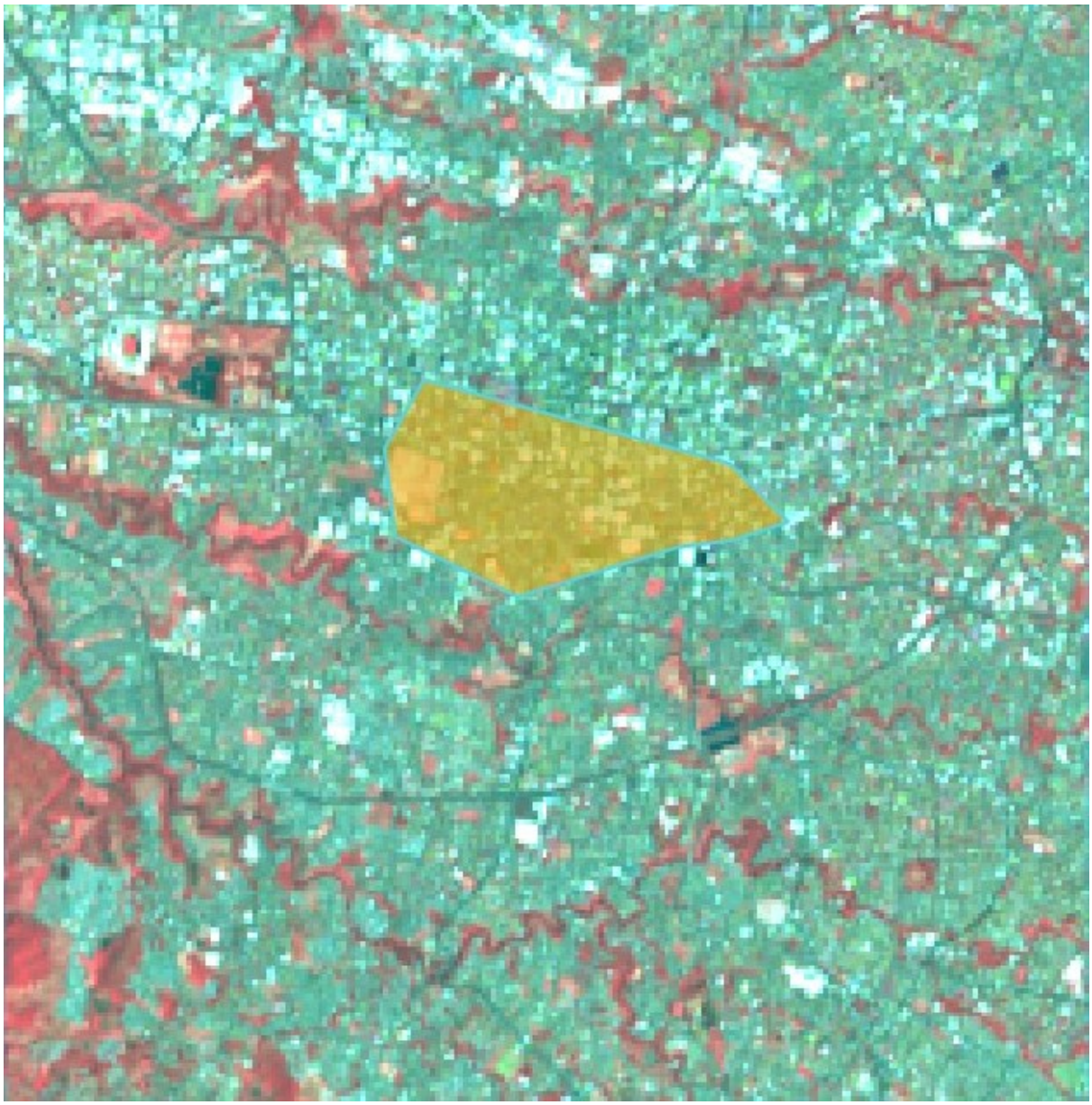


Fig. 20.8: *Example of Built-up ROI*

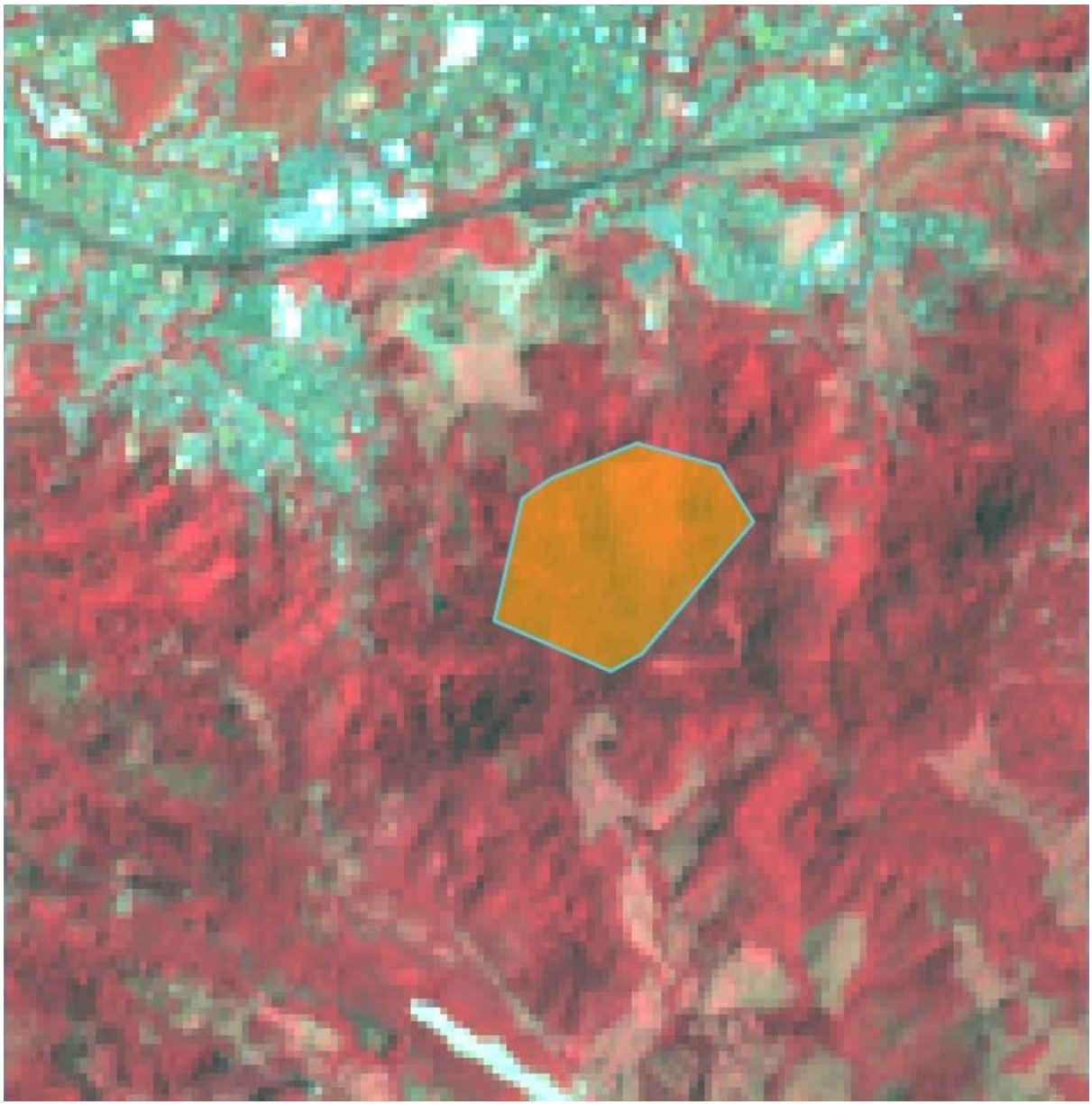


Fig. 20.9: *Example of Vegetation ROI*

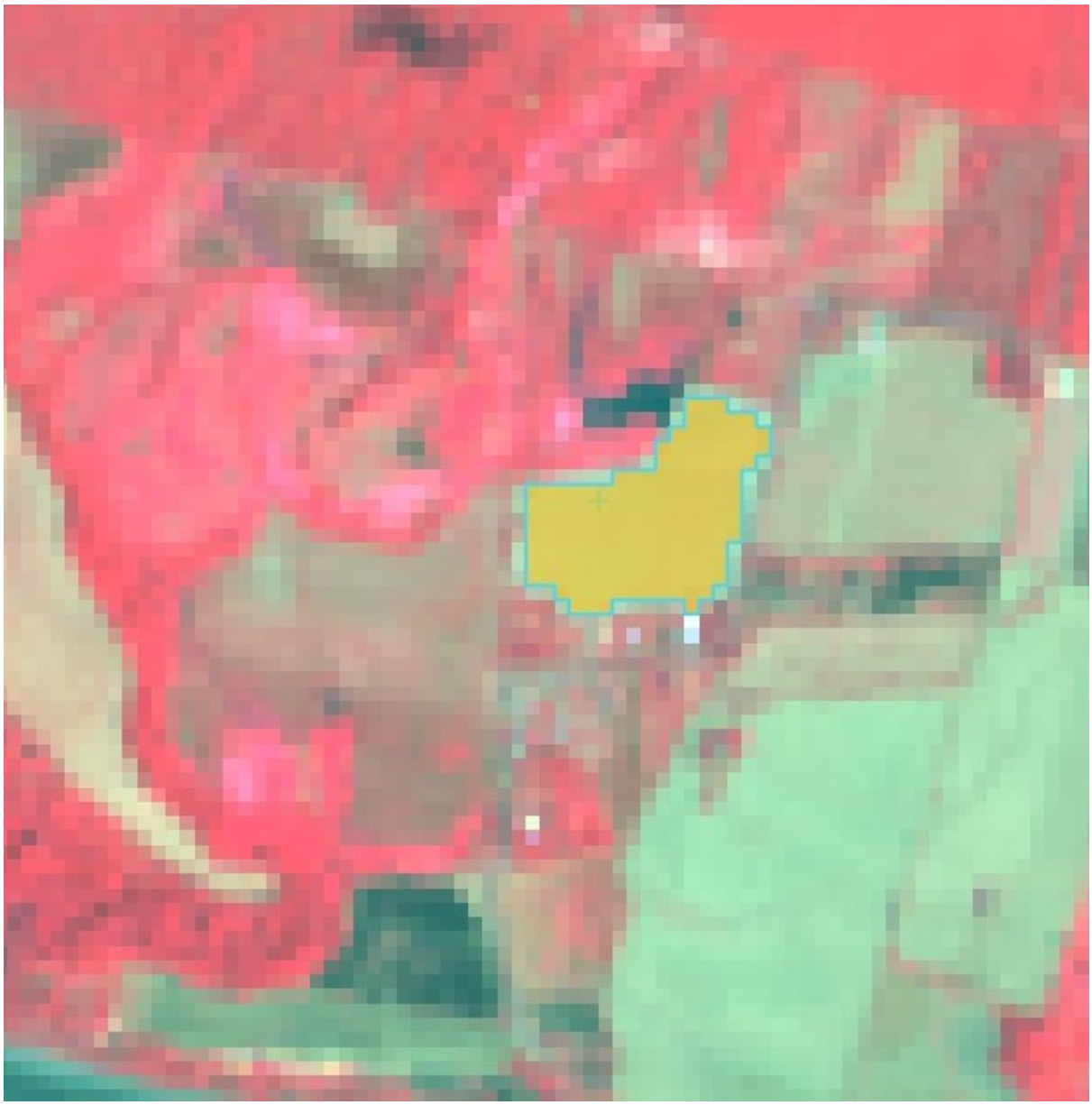


Fig. 20.10: *Example of Soil ROI*

Fig. 20.11: *Example of Water ROI*

TIP : change frequently the *Color Composite* (page 35) and use the buttons and in the *Toolbar* (page 87) for stretching the minimum and maximum values of the displayed image; also, use the button `Show` for hiding and showing the image.

ROIs are used for the calculation of spectral signatures that are used by the classification algorithm in order to classify the entire image. In this tutorial we are going to use the *Maximum Likelihood* (page 41) algorithm.

After the creation of each ROI it is useful to check the *Spectral Distance* (page 42) in order to assess the separability of ROI; in fact, each ROI should be different (i.e. spectrally distant) from the others, in order to avoid spectral confusion and achieve better classification results.

In the *Signature list* (page 95) highlight the ROIs and click the button . Spectral signature are added to the *Spectral Signature Plot* (page 135).

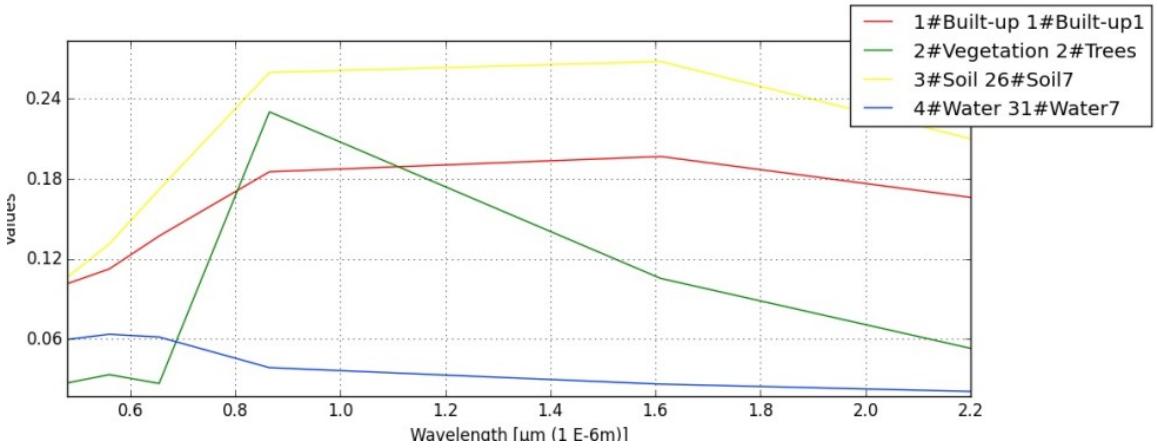


Fig. 20.12: *Plot of spectral signatures*

Now click the tab *Spectral distances* (page 138). Each table represent the *Spectral Distance* (page 42) of each ROI combination.

As shown in the following figure, the comparison of the Built-up ROI and the Soil ROI highlights very low *Spectral Angle* (page 43) and *Euclidean Distance* (page 43); this means high similarity if we used the *Spectra Angle Mapping* (page 42) or the *Minimum Distance* (page 40) algorithms. The *Jeffries-Matusita Distance* (page 42) is near 2; this means that the two ROIs are separable for the *Maximum Likelihood* (page 41) algorithm.

Since we are using the *Maximum Likelihood* (page 41) algorithm, it is important that the *Jeffries-Matusita Distance* (page 42) is near 2 for each ROI combination.

Now we can create a classification preview (see *Create a Classification Preview* (page 61) for the basics of classification previews).

In the *Classification algorithm* (page 97) select the classification algorithm `Maximum Likelihood`. In *Classification preview* (page 98) set `Size` = 500 , click the button + and then **left click** in the map in order to create a classification preview. Use the `Transparency` tool for changing the preview transparency and display the classification over the image.

In the *Classification algorithm* (page 97), click the button + and then **right click** in the map for calculating the `algorithm raster`. The `algorithm raster` represents the calculation result of the *Classification Algorithms* (page 40); it is useful for locating where we need to create new ROIs.

As shown in the following figure, the `algorithm raster` has a grey scale symbology, where dark areas represent pixels that the algorithm found distant from all the spectral signatures and white areas represents pixels that are very similar to spectral signatures. In these dark areas we have a greater level of uncertainty, therefore we need to create new ROIs in order to improve the classification results.

We can notice the presence of clouds in the image. In order to avoid classification errors, we need to mask clouds.

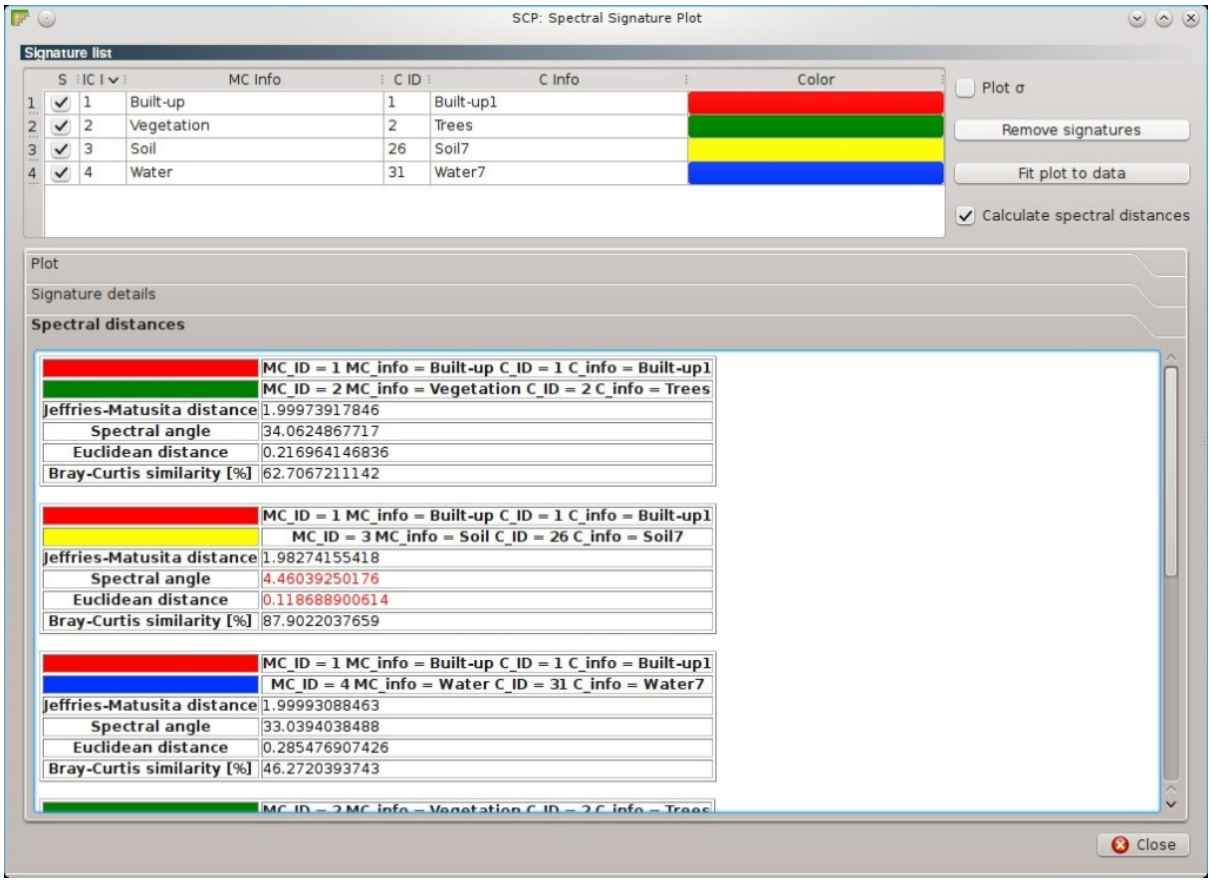

SCP: Spectral Signature Plot
Signature list
S
IC I
MC Info
C ID
C Info
Color
1 1 Built-up 1 Built-up1
2 2 Vegetation 2 Trees
3 3 Soil 26 Soil7
4 4 Water 31 Water7
Plot σ
Remove signatures
Fit plot to data
Calculate spectral distances
Plot
Signature details
Spectral distances
MC_ID = 1 MC_info = Built-up C_ID = 1 C_info = Built-up1
MC_ID = 2 MC_info = Vegetation C_ID = 2 C_info = Trees
Jeffries-Matusita distance 1.99973917846
Spectral angle 34.0624867717
Euclidean distance 0.216964146836
Bray-Curtis similarity [%] 62.7067211142
MC_ID = 1 MC_info = Built-up C_ID = 1 C_info = Built-up1
MC_ID = 3 MC_info = Soil C_ID = 26 C_info = Soil7
Jeffries-Matusita distance 1.98274155418
Spectral angle 4.46039250176
Euclidean distance 0.118688900614
Bray-Curtis similarity [%] 87.9022037659
MC_ID = 1 MC_info = Built-up C_ID = 1 C_info = Built-up1
MC_ID = 4 MC_info = Water C_ID = 31 C_info = Water7
Jeffries-Matusita distance 1.99993088463
Spectral angle 33.0394038488
Euclidean distance 0.285476907426
Bray-Curtis similarity [%] 46.2720393743
Close

Fig. 20.13: *Spectral distances*

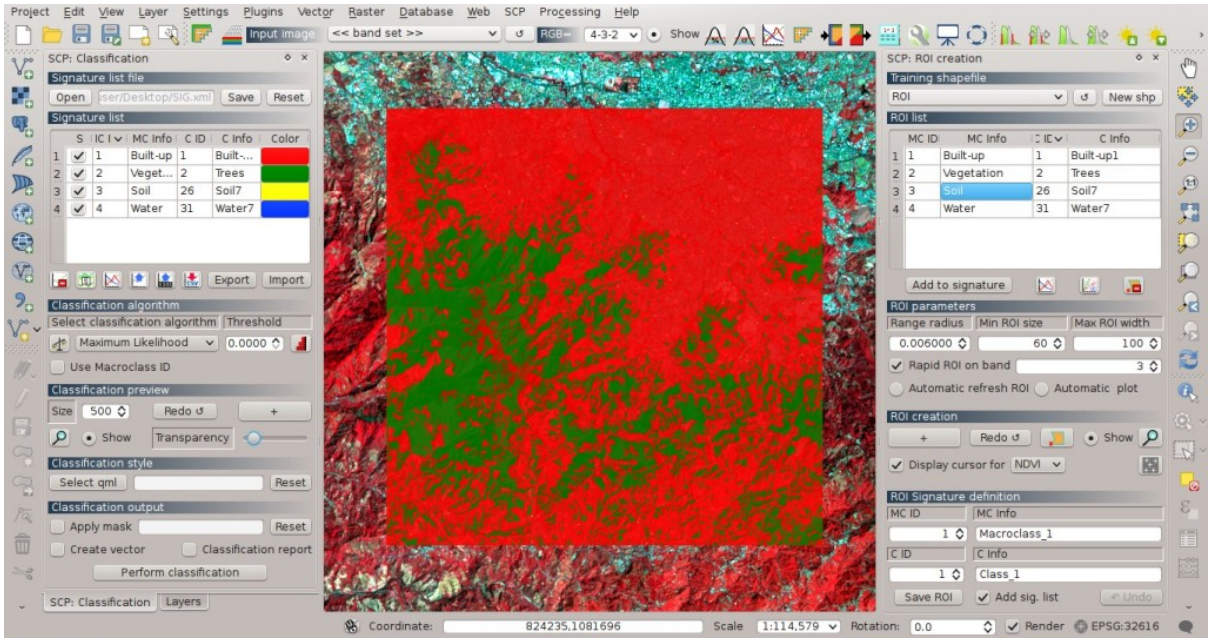


Fig. 20.14: *Classification preview*

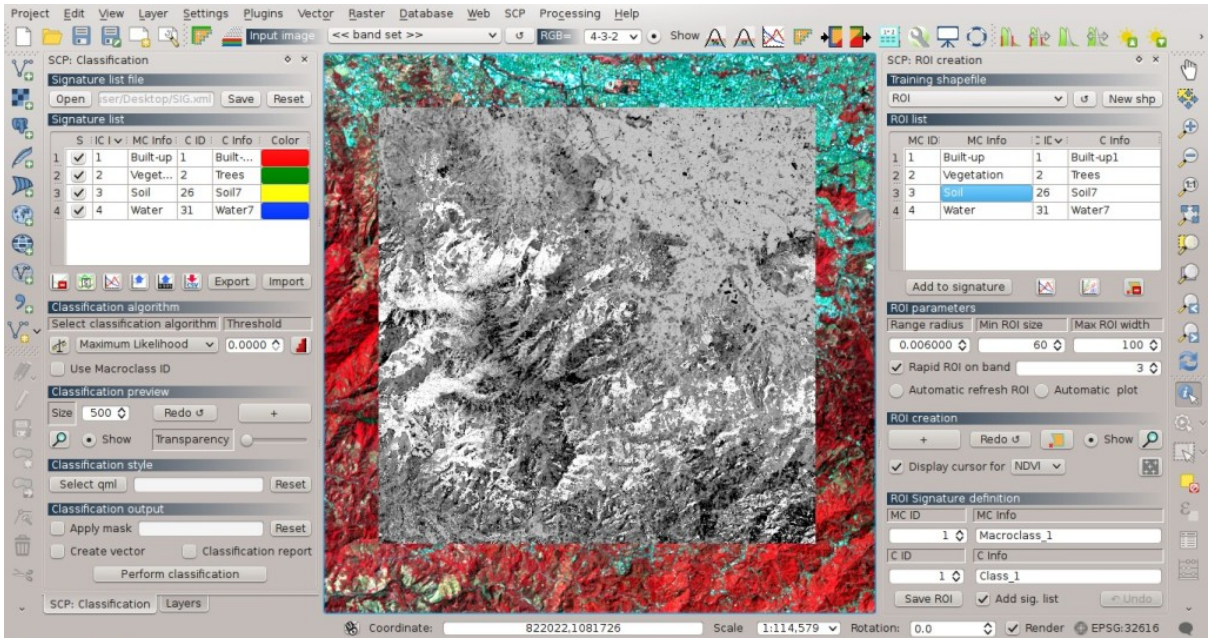


Fig. 20.15: *Preview of the algorithm raster*

There are several methods for masking clouds; during the classification step, a simple method for masking clouds is the creation of ROIs. Create a new ROI inside a cloud in the image, and assign a unique Class ID and the Macroclass ID equals to 0. In fact, the MC ID = 0 is used by SCP for the category `Unclassified`, which means that cloud pixels are not classified (i.e. masked).

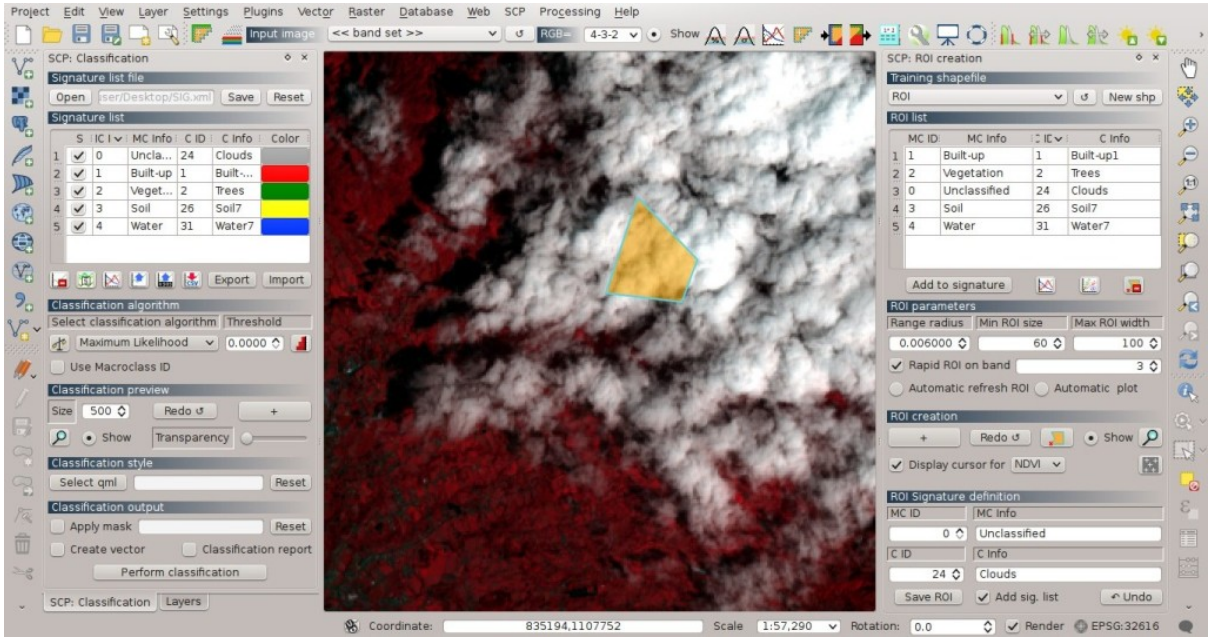


Fig. 20.16: *ROI created for cloud masking*

In the following image, we can see that clouds are now masked. However, pixels near the border of clouds are classified incorrectly as Built-up. In the next paragraphs, more effective methods are described for masking clouds after the classification process (see *Cloud Masking* (page 170)).

When we are happy with the results of the previews, we can perform the classification of the whole image. In *Classification algorithm* (page 97), activate the checkbox `Use Macroclass ID`. In the *Classification output* (page 99) click the button `Perform classification` and define the name of the classification output (e.g.

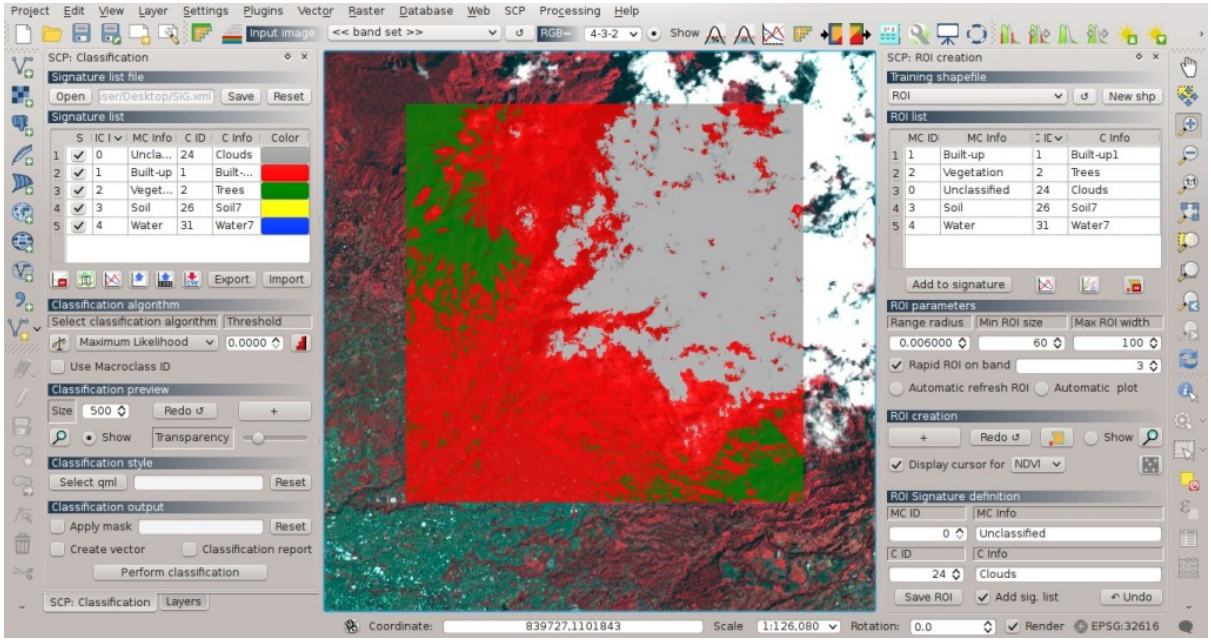


Fig. 20.17: *Classification preview over clouds*

TIP : load a service such as OpenStreetMap using the OpenLayers Plugin, which can ease the photo interpretation and the ROI creation.

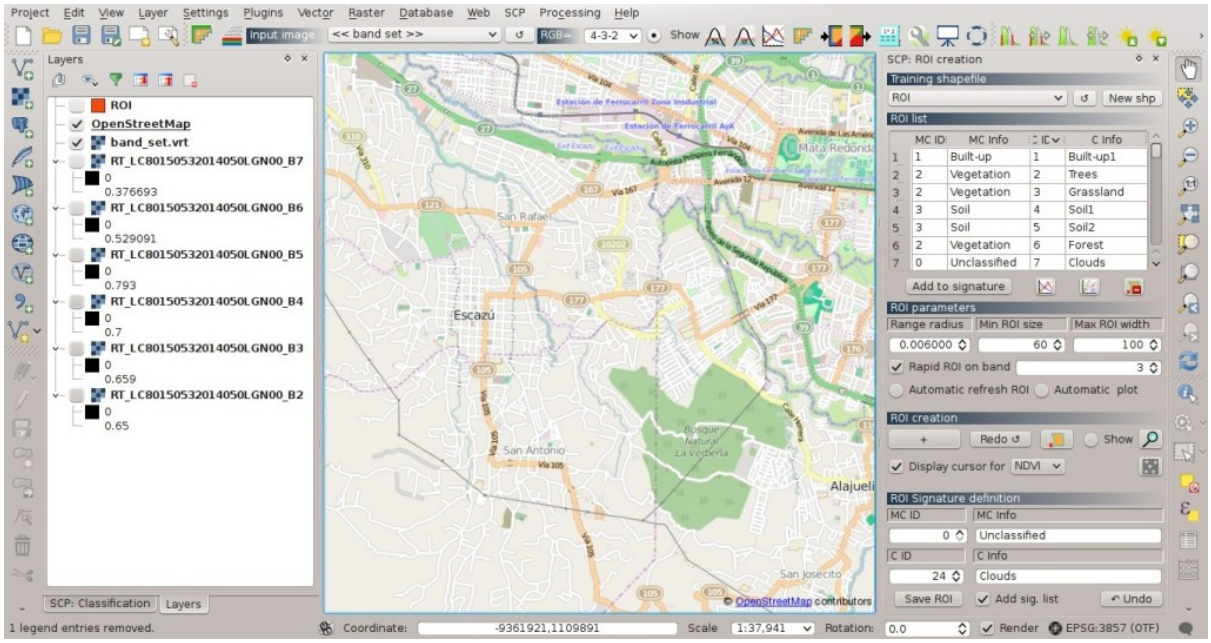


Fig. 20.18: *OpenStreetMap loaded in QGIS*

`classification_1.tif`).

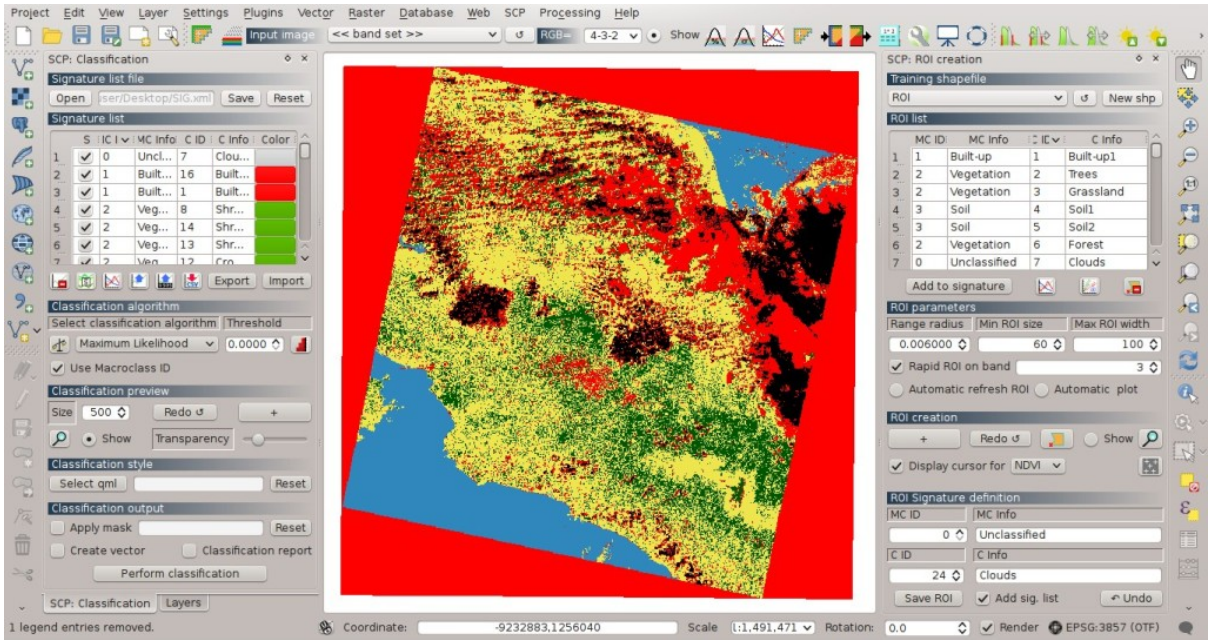


Fig. 20.19: *Land cover classification 1 of the Landsat image LC80150532014050LGN00*

We can see that part of the clouds are black (i.e. unclassified), however several cloud pixels are classified as Built-up. Also, the black border of the Landsat image is classified as Built-up. We are going to correct these errors and refine the classification in the next steps.

Now, in QGIS open the following Landsat 8 bands that are inside the directory `LC80160532014057LGN00_converted`.

- RT_LC80160532014057LGN00_B2.tif = Blue;
- RT_LC80160532014057LGN00_B3.tif = Green;
- RT_LC80160532014057LGN00_B4.tif = Red;
- RT_LC80160532014057LGN00_B5.tif = Near-Infrared;
- RT_LC80160532014057LGN00_B6.tif = Short Wavelength Infrared 1;
- RT_LC80160532014057LGN00_B7.tif = Short Wavelength Infrared 2.

Repeat the above steps for the creation of the Band set, the `Training shapefile` and `Signature list file`.

> **TIP** : close QGIS and create a new QGIS project for each Landsat image, in order to delete temporary files and free disk space.

Create a land cover classification repeating the steps previously described.

In a new QGIS project, open the Landsat 7 bands inside the directory `LE70150532014090EDC00_converted`:

- RT_LE70150532014090EDC00_B1.tif = Blue;
- RT_LE70150532014090EDC00_B2.tif = Green;
- RT_LE70150532014090EDC00_B3.tif = Red;
- RT_LE70150532014090EDC00_B4.tif = Near-Infrared;
- RT_LE70150532014090EDC00_B5.tif = Short Wavelength Infrared 1;
- RT_LE70150532014090EDC00_B7.tif = Short Wavelength Infrared 2.

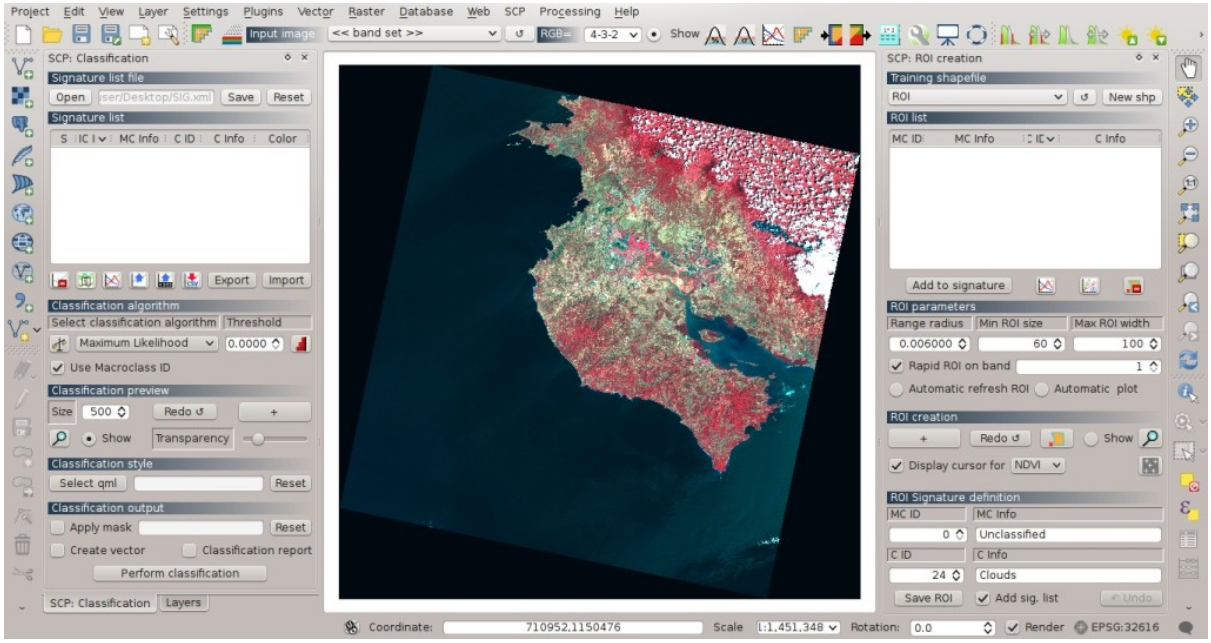


Fig. 20.20: *Definition of SCP input for the Landsat image LC80160532014057LGN00*

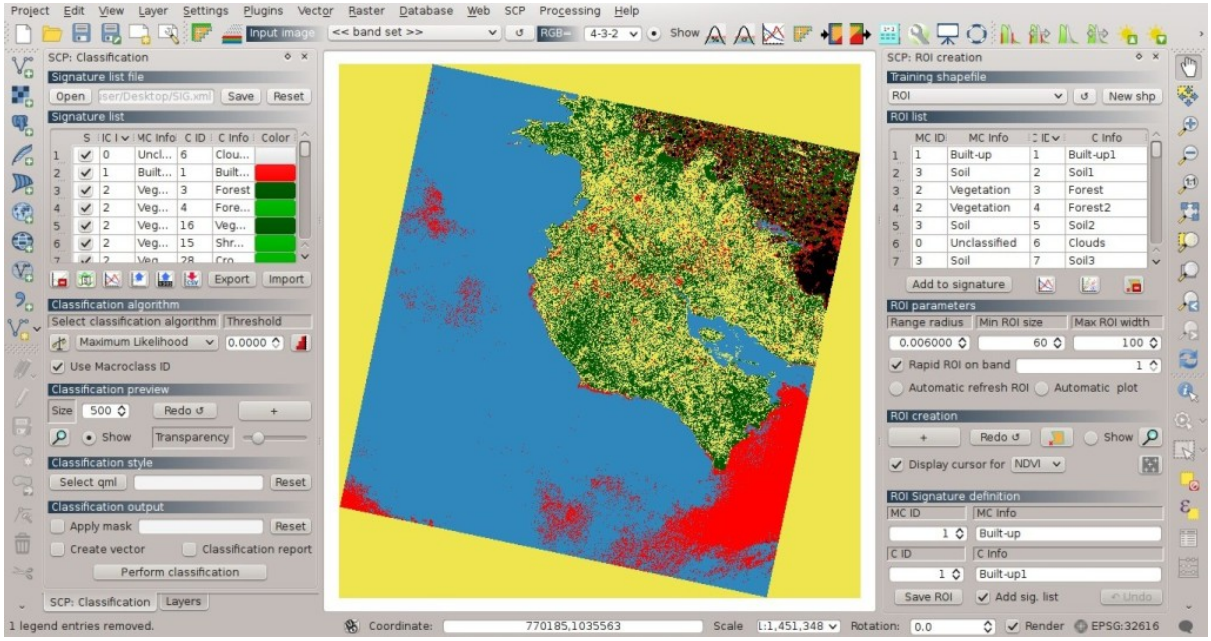


Fig. 20.21: *Land cover classification 2 of the Landsat image LC80160532014057LGN00*

You can see that this image covers the same area as the Landsat 8 image `LC80150532014050LGN00`. In fact, we are going to use the classification of this Landsat 7 image in order to fill the Unclassified pixels of the Landsat 8 image.

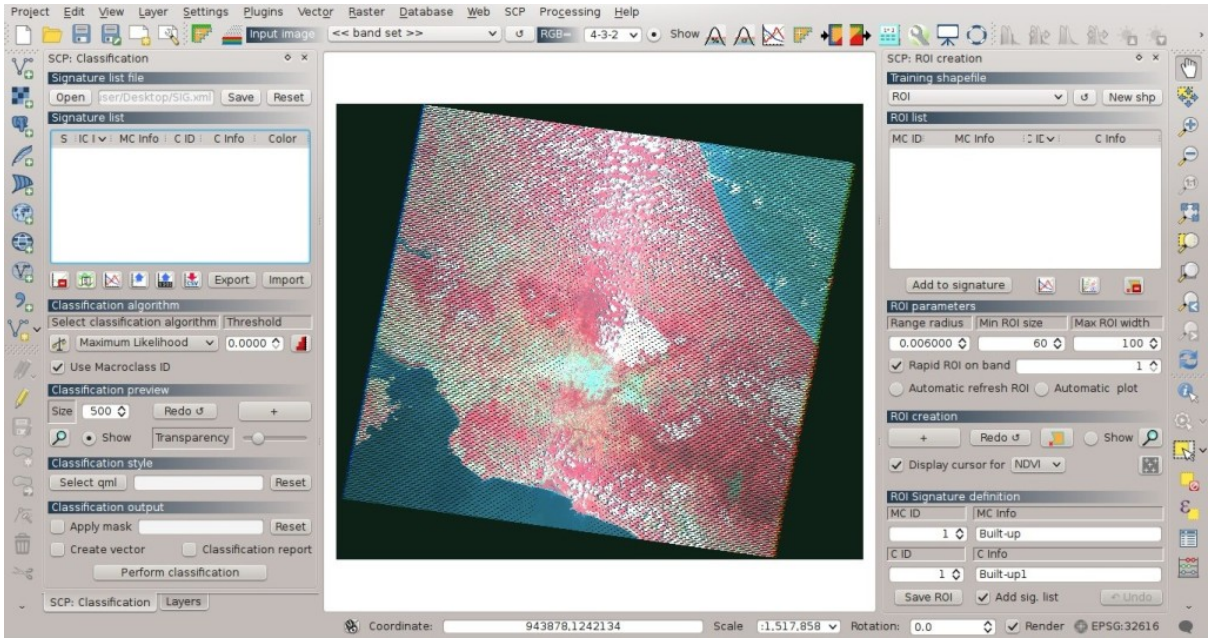


Fig. 20.22: *Definition of SCP input for the Landsat image LE70150532014090EDC00*

Again, create a land cover classification following the steps previously described.

Now, we have 3 land cover classifications that we can enhance in several ways.

20.4 Enhancement of Classification Using NDVI

We are going to calculate NDVI for enhancing the classification using the *Band calc* (page 125) (see *Tutorial: Using the tool Band calc* (page 179)). In particular, pixels where NDVI value is above a certain threshold will be classified as vegetation (code 2). Below this NDVI threshold, the Maximum Likelihood classification is untouched.

Of course, this is an example of integration of ancillary data; we could use other data such as other vegetation indices or the result of other classifications (e.g. using *Spectra Angle Mapping* (page 42)).

Now, in QGIS load the bands of the Landsat 8 image `LC80150532014050LGN00` and the respective land cover classification. Open the *Band calc* (page 125) and click the button `Refresh list`. In the *Band calc* (page 125), calculate the NDVI copying the following *Expression* (page 126):

```
("RT_LC80150532014050LGN00_B5" - "RT_LC80150532014050LGN00_B4")  /  ("RT_LC8015053201405OLGN00_B5
```

Click the button `Calculate`, select where to save the NDVI (e.g. a new file named `NDVI_1.tif`).

Then, calculate the following *Expression* (page 126) for enhancing the classification basing on the NDVI:

```
np.where("NDVI_1" > 0.6, 2, "classification_1")
```

Click the button `Calculate`, and select where to save the new classification (e.g. `classification_1_NDVI.tif`). We can see in the following figure that the area classified as vegetation has increased.

In this case we have used a NDVI threshold equals to 0.6 . However, the threshold value has to be chosen for every image, because NDVI can vary from image to image.

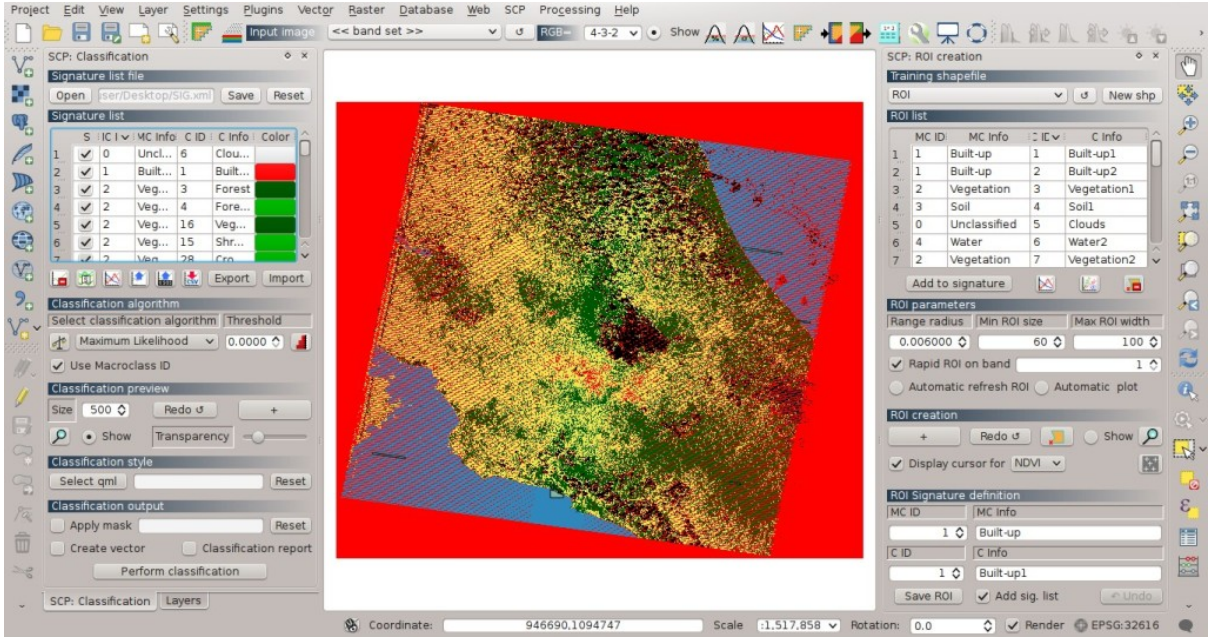


Fig. 20.23: *Land cover classification 3 of the Landsat image LE70150532014090EDC00*

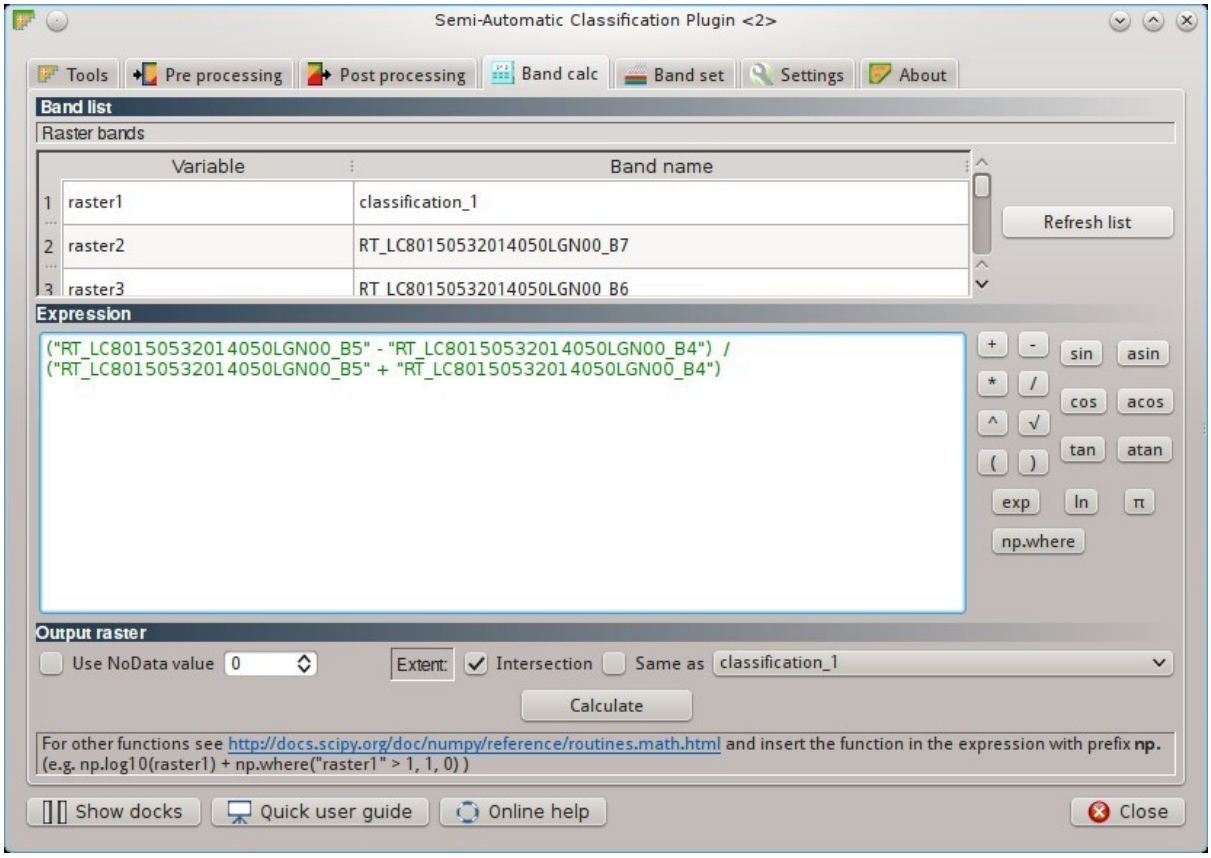


Fig. 20.24: *NDVI calculation*

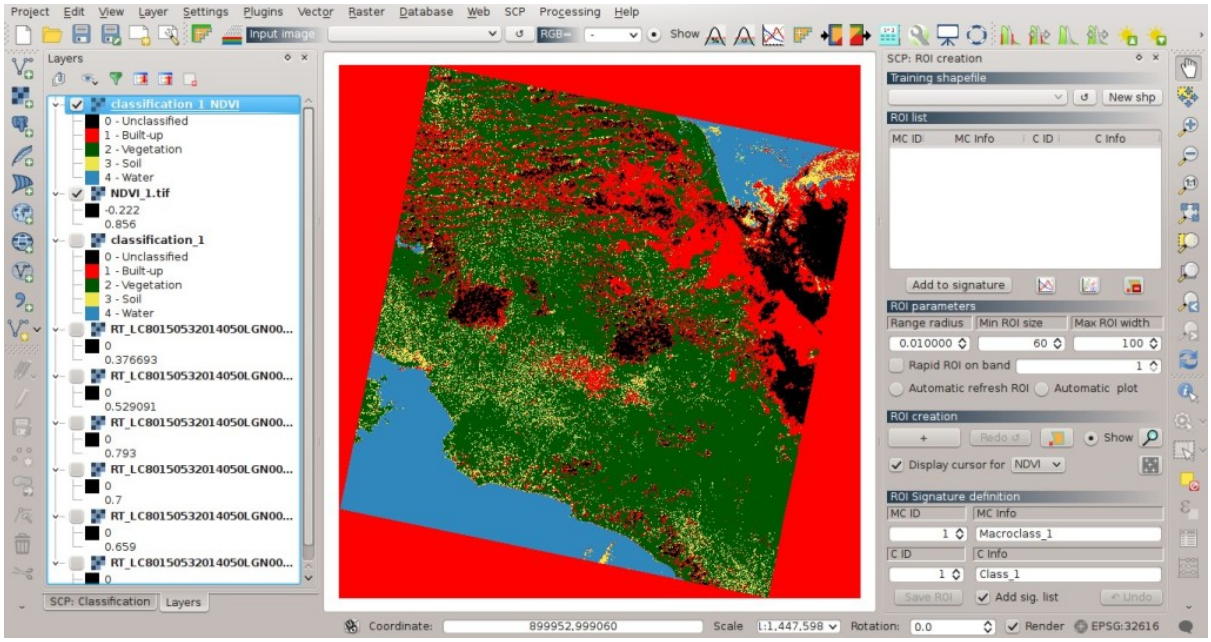


Fig. 20.25: *Classification 1 refined with NDVI*

Now we perform the same enhancement for the other land cover classifications. For the Landsat 8 image `LC80160532014057LGN00` calculate NDVI with the following expression:

```
("RT_LC80160532014057LGN00_B5" - "RT_LC80160532014057LGN00_B4")  /  ("RT_LC80160532014057LGN00_B5
```

and the following expression for enhancing the classification:

```
np.where("NDVI_2" > 0.5, 2, "classification_2")
```

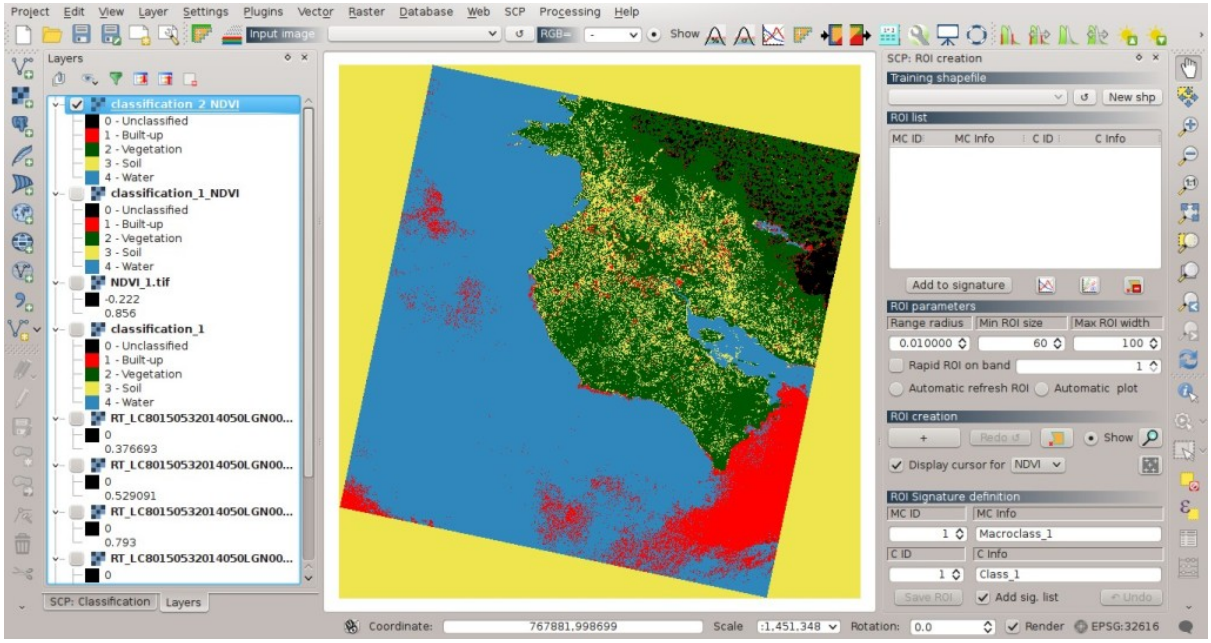


Fig. 20.26: *Classification 2 refined with NDVI*

For the Landsat 7 image `LE70150532014090EDC00` calculate NDVI with the following expression:

```
("RT_LE70150532014090EDC00_B4" - "RT_LE70150532014090EDC00_B3")  /  ("RT_LE70150532014090EDC00_B4
```

and the following expression for enhancing the classification:

```
np.where("NDVI_3" > 0.5, 2, "classification_3")
```

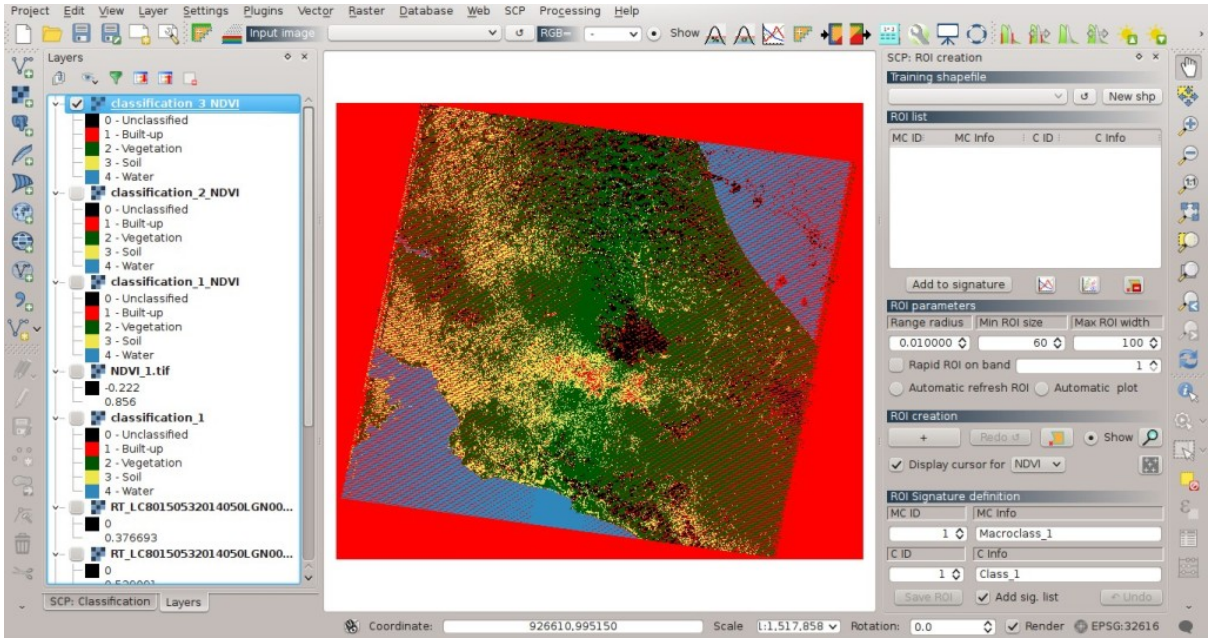


Fig. 20.27: *Classification 3 refined with NDVI*

Now that the classification of vegetation has been enhanced for the three images, we are going to mask clouds and border pixels in order to avoid classification errors.

20.5 Cloud Masking

Landsat 8 images include Quality Assessment bands (QA) that are useful for identifying clouds. Pixel values of QA bands are codes that represent combinations of surface and atmosphere conditions. These values indicate with high confidence cirrus or clouds pixels (for the description of these codes see the table at http://landsat.usgs.gov/L8QualityAssessmentBand.php).

The QA band of the Landsat 8 image `LC80150532014050LGN00` includes mainly the values 53248 and 61440 indicating clouds, and the value 36864 indicating potential clouds. Therefore, we are going to write an expression that masks our classification (i.e. `classification_1_NDVI`) where pixels of the QA band are equal to one of these values.

In QGIS, open the band `LC80150532014050LGN00_BQA` that is inside the directory `LC80150532014050LGN00` of the downloaded Landsat image and the `classification_1_NDVI`. Copy the following *Expression* (page 126) in the *Band calc* (page 125):

```
np.where(("LC80150532014050LGN00_BQA" == 53248) | ("LC80150532014050LGN00_BQA" == 36864) | ("LC80
```

Click the button `Calculate`, and select where to save the new classification (e.g. `classification_1_clouds.tif`).

Clouds are almost completely masked (i.e. Unclassified); however, some pixels are still classified as Built-up (in red). We can do the same for the image `LC80160532014057LGN00` using the following *Expression* (page 126) in the *Band calc* (page 125):

```
np.where(("LC80160532014057LGN00_BQA" == 53248) | ("LC80160532014057LGN00_BQA" == 36864) | ("LC80
```

The Landsat 7 image does not have the QA band. Another method for masking clouds uses the Blue and the Thermal Infrared (converted to temperature) bands, basing on the fact that clouds are generally colder than soil

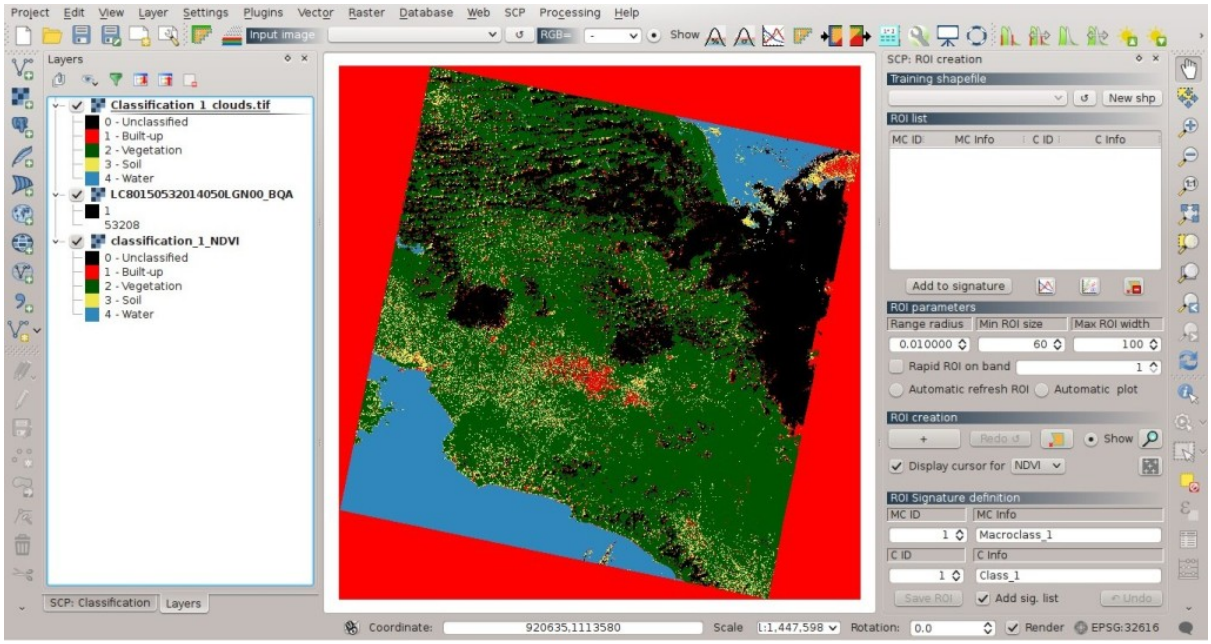


Fig. 20.28: *Classification 1 with masked clouds*

and have high reflectance values in the blue band. Landsat 7 is also affected by black stripes (i.e. SLC-off) that we are going to mask as well.

We are going to create an expression that identifies pixel values below a certain temperature threshold for the Thermal band (band 6 for Landsat 7), and above a certain reflectance threshold for the Blue band (band 1).

In QGIS load all the Landsat bands inside the directory `LE70150532014090EDC00_converted`. Use the following expression in the *Band calc* (page 125):

```
np.where((("RT_LE70150532014090EDC00_B6_VCID_1"<23) & ("RT_LE70150532014090EDC00_B1">0.1)) | ("RT_
```

The first part `(("RT_LE70150532014090EDC00_B6_VCID_1"<23) & ("RT_LE70150532014090EDC00_B1">0.1))` means that we are going to mask pixels that have both temperature lower than 23°C and Blue band reflectance greater than 0.1 . These threshold values have been identified in the image, using the tool `Identify` of QGIS for cloud pixels in band 1 and band 6.

The character `|` means `or` , so that the other expressions (e.g. `"RT_LE70150532014090EDC00_B1" == 0`) identify pixel values equal to 0 (which are NoData) for every Landsat band, in order to mask the black stripes due to SLC-off and the black border.

We could use the same method of cloud masking also for Landsat 8 images. For the image `LC80150532014050LGN00` load the bands `RT_LC80150532014050LGN00_B10` and `RT_LC80150532014050LGN00_B2`, and use the following *Expression* (page 126) in the *Band calc* (page 125):

```
np.where((("RT_LC80150532014050LGN00_B2" > 0.03) & ("RT_LC80150532014050LGN00_B10" < 24)) | ("RT_
```

The condition `"RT_LC80160532014057LGN00_B2" == 0` allows for the masking of the image black border.

As you can see, there are still gaps (Unclassified pixels) in the classification; we would require the classification of other Landsat images in order to fill those gaps. After the cloud masking of these three classifications, we can create one mosaic that is the classification of the whole study area.

Part of the unclassified gaps has been filled with the Landsat 7 classification. Of course, we would require more classifications in order to fill all the gaps.

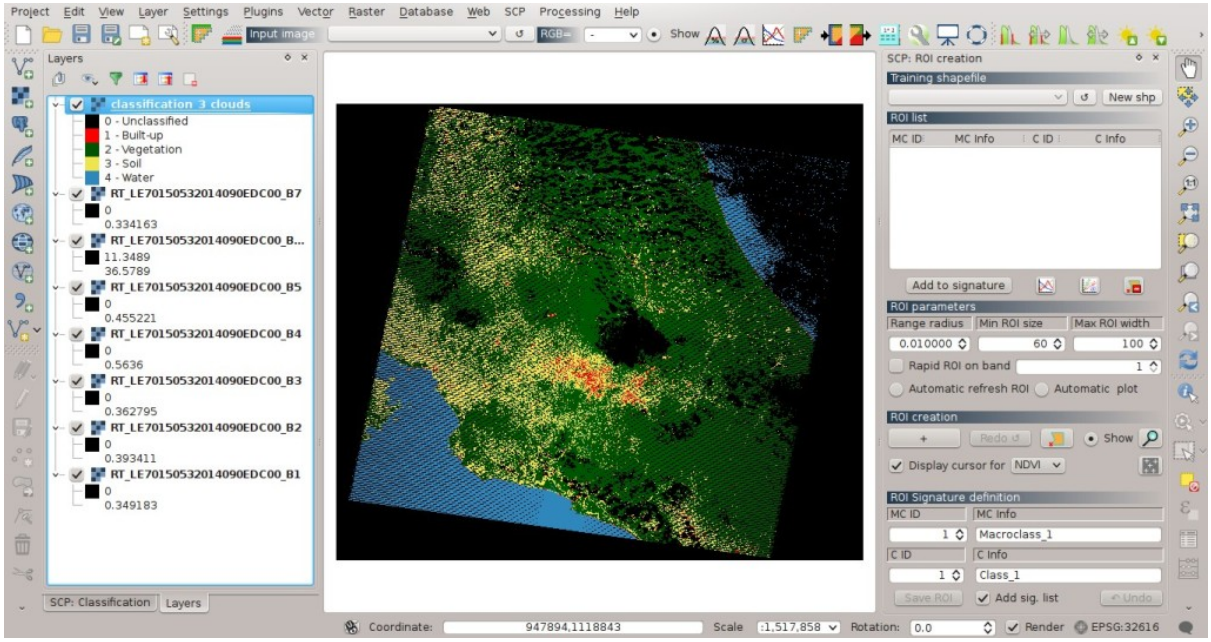


Fig. 20.29: *Classification 3 with masked clouds*

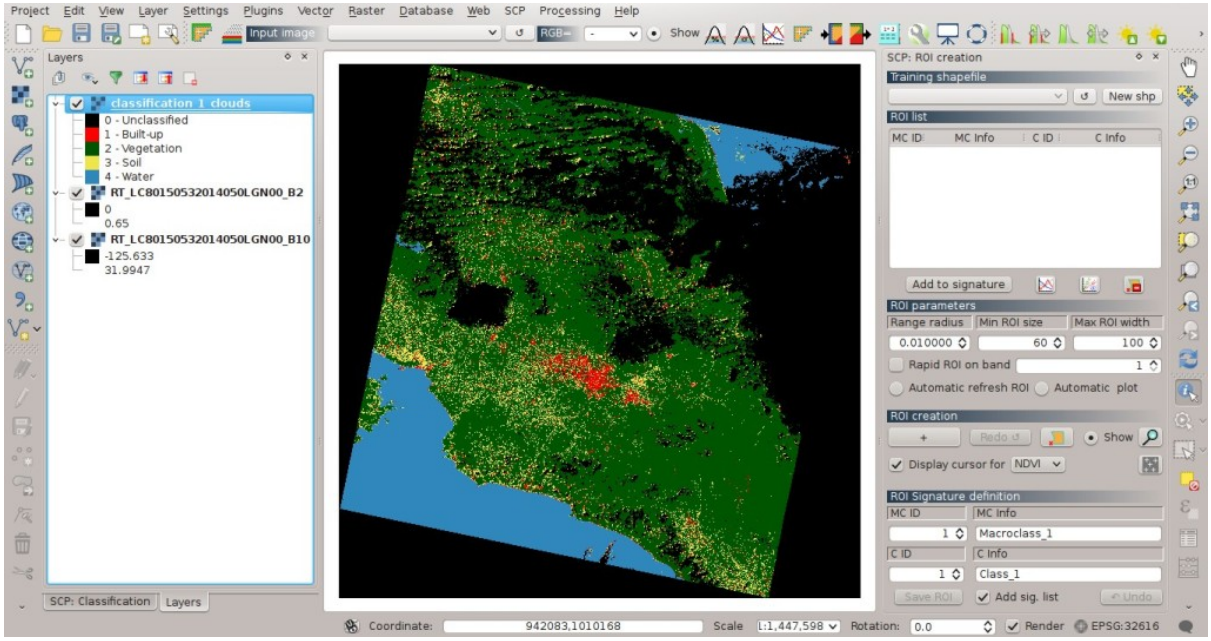


Fig. 20.30: *Classification 1 with clouds masked using the alternative method*

20.6 Mosaic of Classifications

In order to create a mosaic of classifications, we are going to write an expression that will fill Unclassified pixels of the Landsat 8 image (ID `LC80150532014050LGN00`) with the classification of the Landsat 7 image (ID `LE70150532014090EDC00`). Also, we are going to merge these classifications to third one (the Landsat 8 image with ID `LC80160532014057LGN00`).

In QGIS open the three cloud masked classifications. Copy the following *Expression* (page 126) in *Band calc* (page 125):

```
np.where("classification_1_clouds" == 0,  np.where("classification_3_clouds" == 0, "classificatio
```

Uncheck the checkbox `Intersection` in *Output raster* (page 127) and click `Calculate`. The result (e.g. `classification_mosaic`) is shown in the following image.

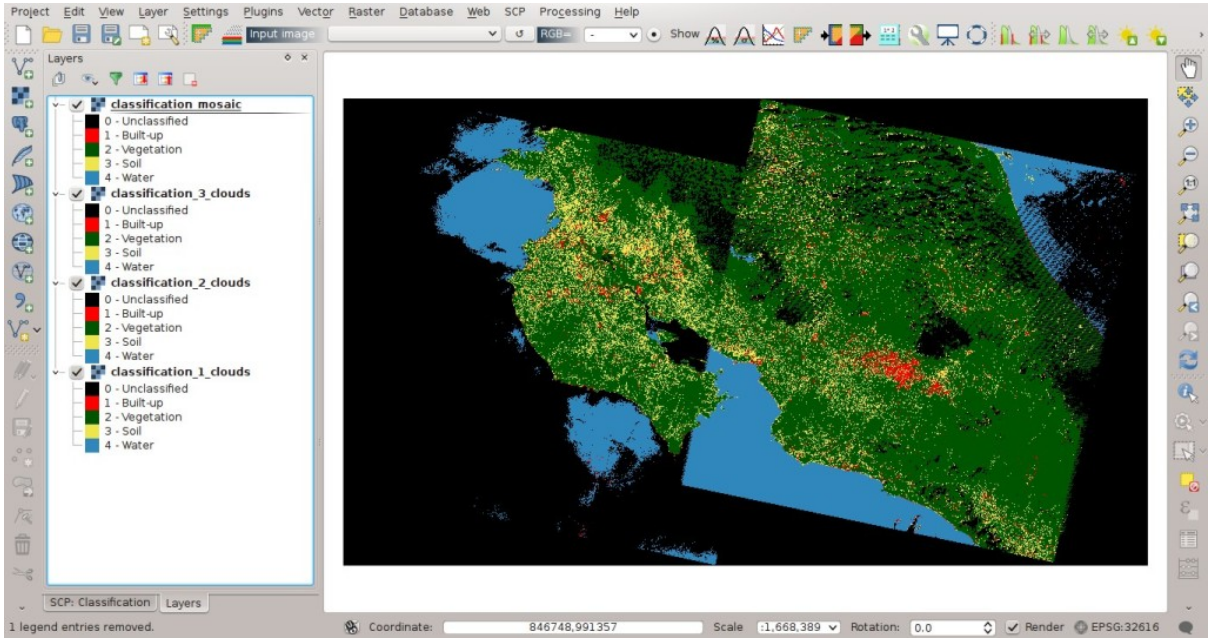


Fig. 20.31: *Classification mosaic*

In the following steps we are going to perform the accuracy assessment and the estimation of land cover area.

20.7 Accuracy Assessment

Accuracy Assessment (page 44) is an important step of a land cover classification. In this tutorial we are going to use the `Training shapefile` as reference for assessing classification accuracy. However, there other methods that can improve the validation reliability (see http://fromgistors.blogspot.com/2014/09/accuracy-assessment-using-random-points.html).

In QGIS, load the classification mosaic and the `Training shapefile` used for the image `LC80150532014050LGN00`. In SCP open the tab *Accuracy* (page 117) and click the buttons `Refresh list`. Select `classification_mosaic` as the classification to assess and the `Training shapefile` as reference shapefile. Also, select `MC_ID` as `Shapefile field`. Click `Calculate error matrix` and choose the output destination (e.g. `accuracy.tif`).

The process produces an `error matrix` and an `error raster` which are useful for assessing the quality of our classification.

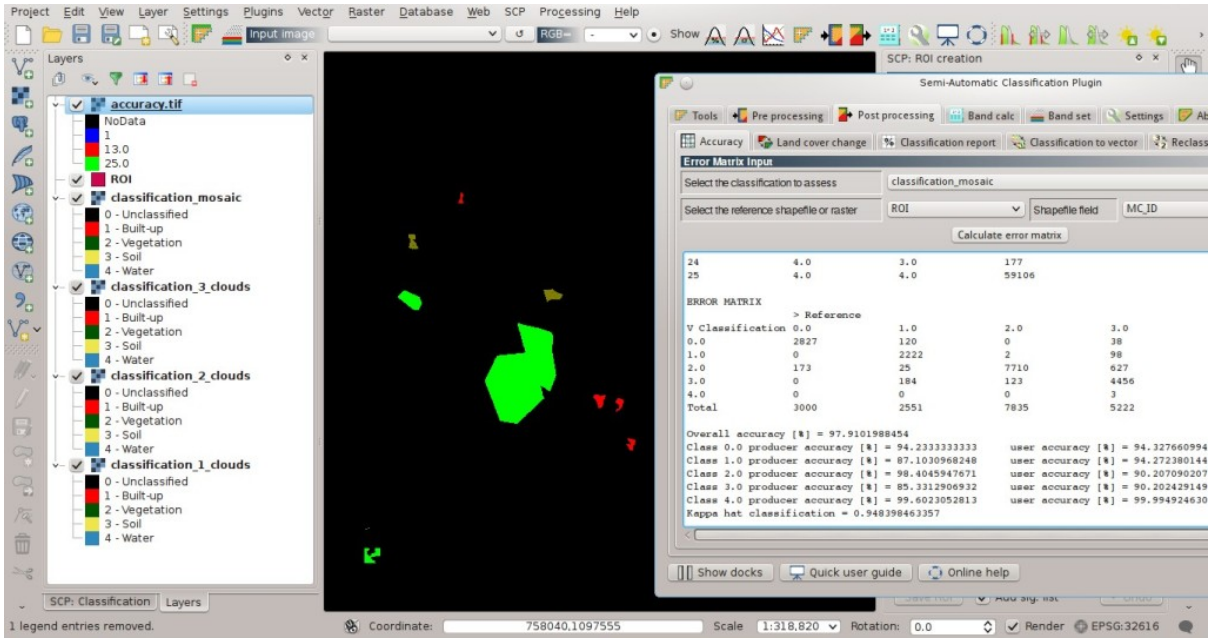


Fig. 20.32: *Accuracy assessment*

20.8 Clip of the Classification

Before calculating the area of each land cover class, we need to clip the classification to the extent of the study area, which is Costa Rica.

Download the Shapefile of Sub-National Administrative Units of Costa Rica from http://data.fao.org/map?entryId=c7a0f990-88fd-11da-a88f-000d939bc5d8&tab=metadata (clicking the Download button) by the FAO .

Extract the downloaded file (`1173.zip`) and load the shapefile `costa rica.shp` in QGIS (select WGS84 as projection).

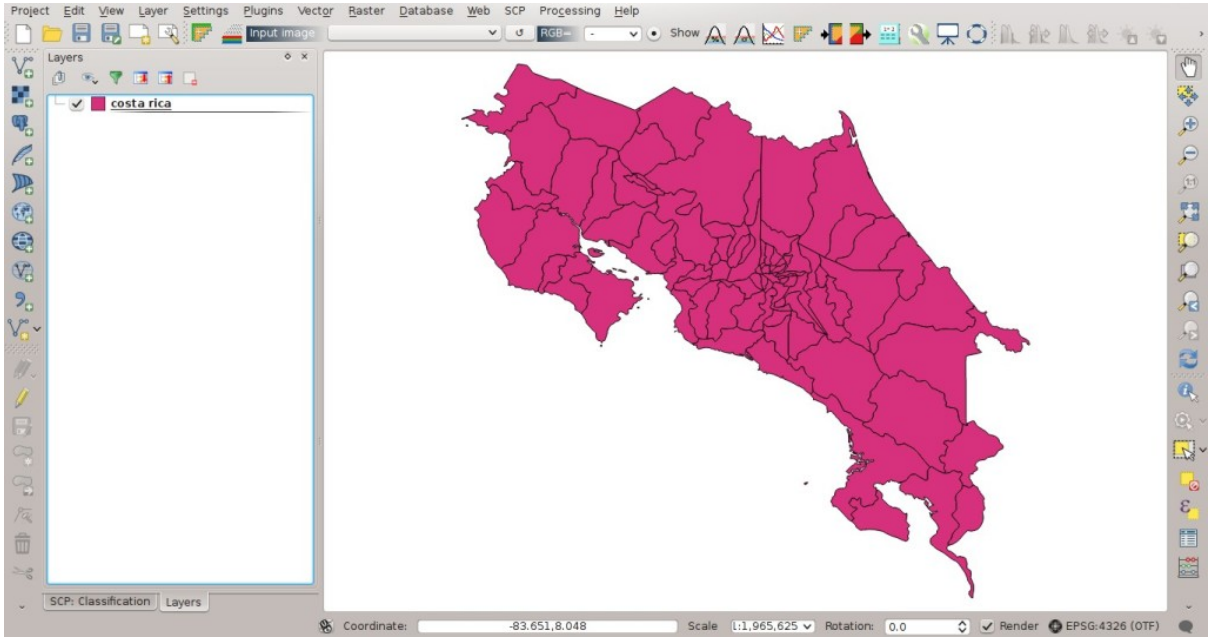


Fig. 20.33: *The shapefile of Costa Rica by FAO*

In this case, we need to define the projection of this shapefile. In QGIS, open the command `Vector > Data management tool > Define current projection`; select the shapefile `costa rica` as `Input vector layer` and choose `EPSG:4326 - WGS 84` as spatial reference, and click `OK`.

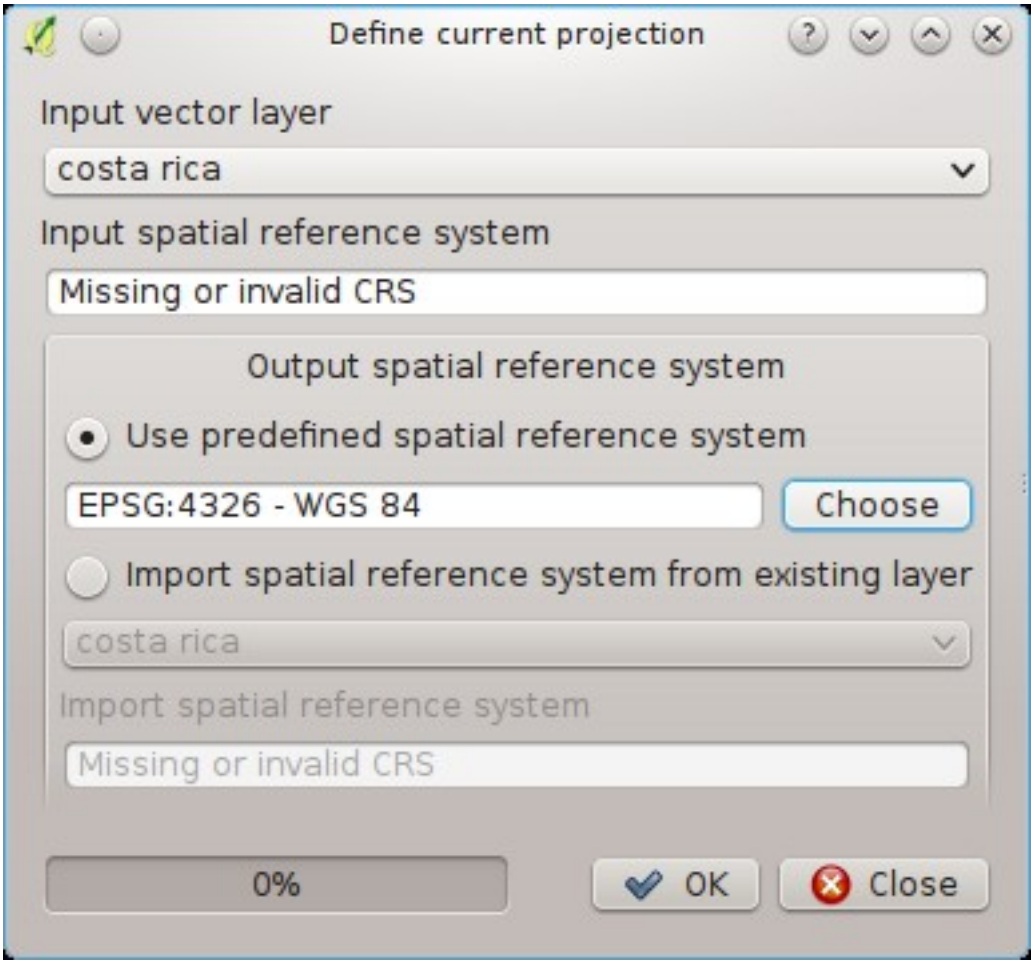


Fig. 20.34: *Define the shapefile projection*

Now we can clip the `classification_mosaic.tif`. Load the classification in QGIS. Open the command `Raster > Extraction > Clipper`. Select the `classification_mosaic` as input raster; set the output file (e.g. `classification_clip.tif`), and set `No data value` equals to 0. In `Clipping mode` enable `Mask layer` and select `costa rica`, then click `OK`.

Finally, we have a classification clipped to the extent of Costa Rica (as you can see we would need other classifications for covering the whole extent of Costa Rica), and we can calculate the classification report.

20.9 Classification Report

In SCP open the tab *Classification report* (page 121) and click the buttons `Refresh list`. Check `Use NoData value` setting the value equals to 0 and click the button `Calculate classification report`. The classification report is displayed with the count of pixels, the area, and percentage of each land cover class. You can save the report to text file clicking the button `Save report to file`.

We have completed this tutorial about the land cover classification of a large area, using multiple Landsat images and creating a classification mosaic. It is worth pointing out that classification results depend on the season of the images. Therefore, the input images should be acquired in the same period, in order to avoid differences due for instance to the phenological state of vegetation or occurred land cover change.

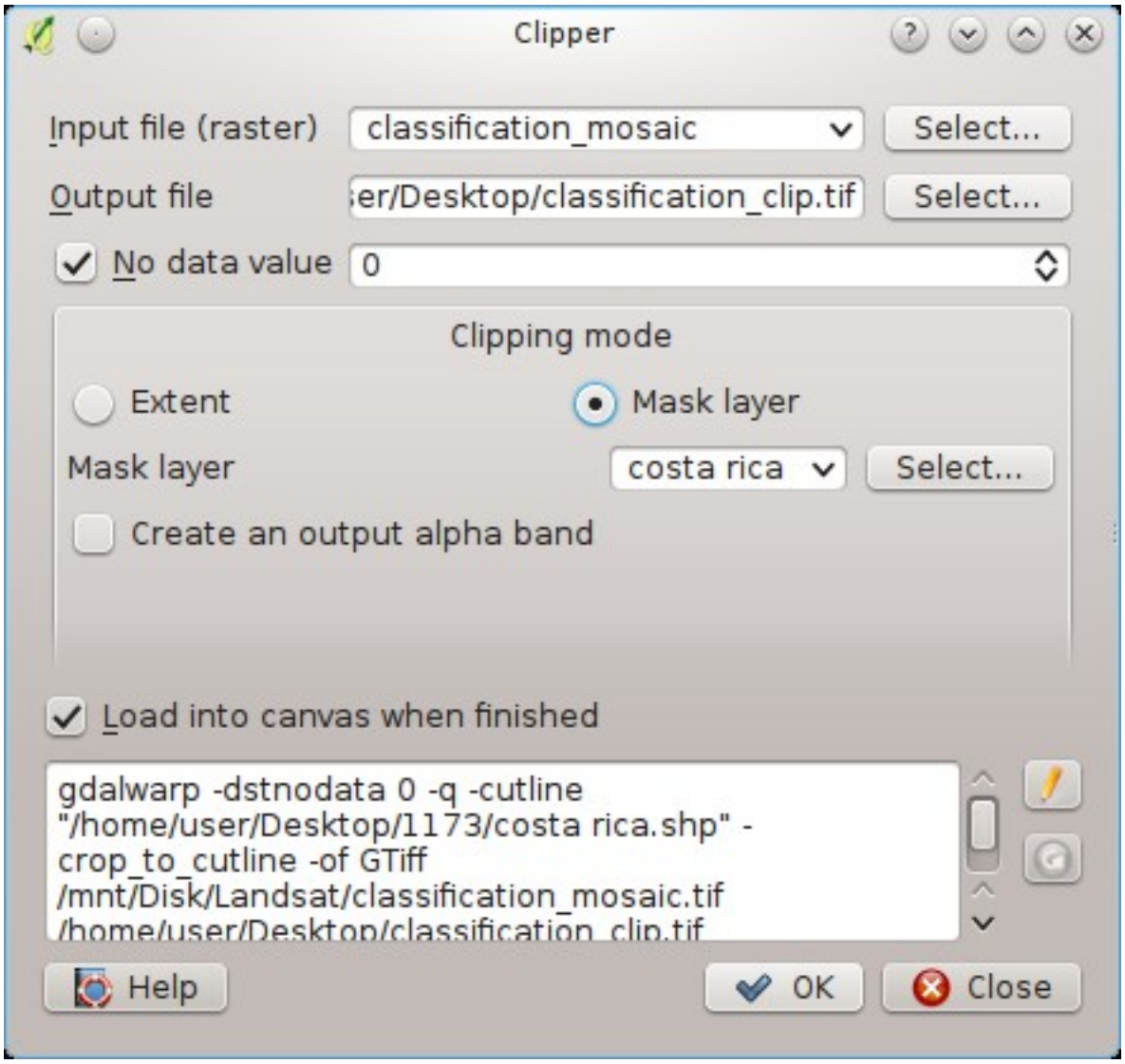


Fig. 20.35: *Clipping the classification*

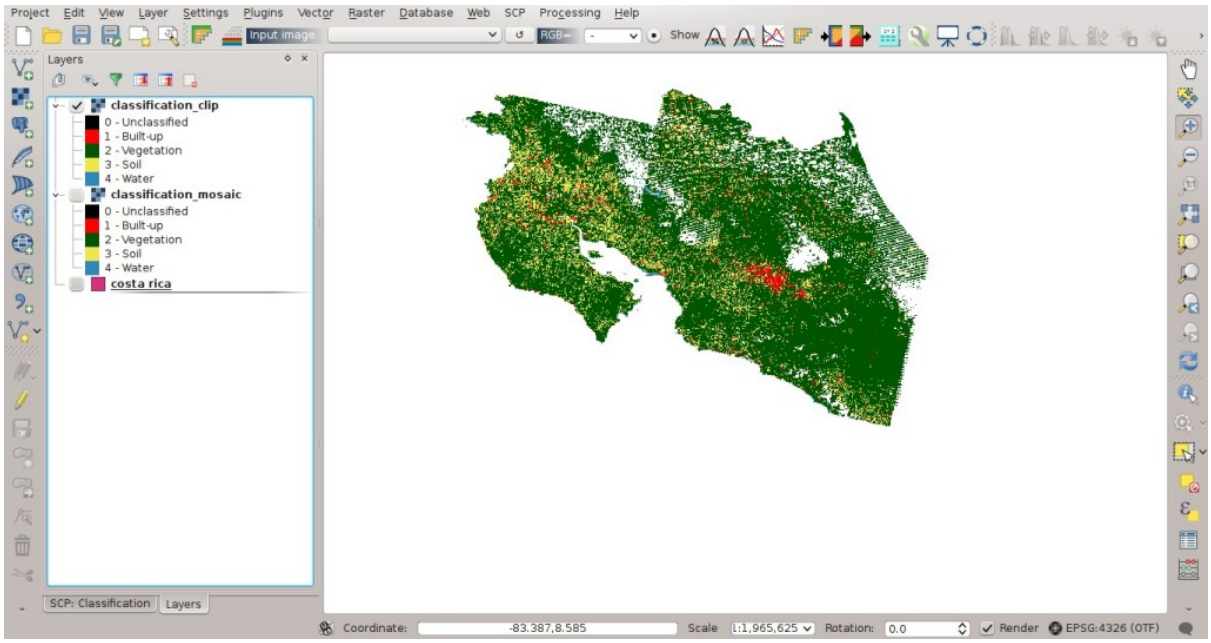


Fig. 20.36: *The clipped classification*

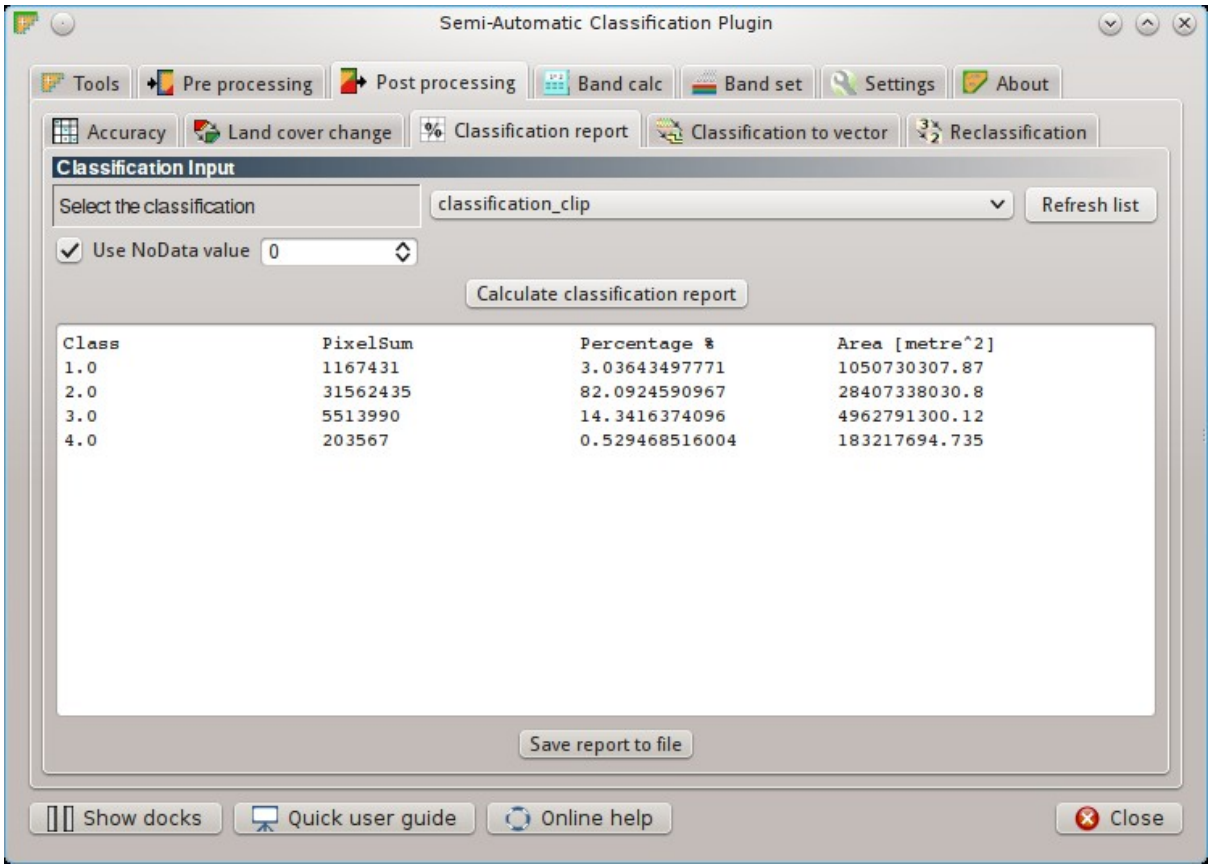


Fig. 20.37: *Classification report*

CHAPTER 21

Tutorial: Using the tool Band calc

This is a tutorial about the use of the tool *Band calc* (page 125) that allows for the **raster calculation for bands**. In particular, we are going to calculate the NDVI (Normalized Difference Vegetation Index) of a Landsat image, and then apply a condition in order to refine a land cover classification (see *Tutorial 2: Land Cover Classification of Landsat Images* (page 65)) basing on NDVI values (a sort of Decision Tree Classifier).

The *Band calc* (page 125) can perform multiple calculations in sequence. We are going to apply a mask to every Landsat bands in order to exclude cirrus and cloud pixels from the NDVI calculation, and avoid anomalous values. In particular, Landsat 8 includes a Quality Assessment Band) that can be used for masking cirrus and cloud pixels.

The values that indicate with high confidence cirrus or clouds pixels are (for the description of these codes see the table at http://landsat.usgs.gov/L8QualityAssessmentBand.php):

- 61440;
- 59424;
- 57344;
- 56320;
- 53248;
- 31744;
- 28672 .

In particular, the Quality Assessment Band of the sample dataset includes mainly the value 53248 indicating clouds. Therefore, in this tutorial we are going to exclude the pixels with the **value 53248** from all the Landsat bands.

Following the video of this tutorial.

http://www.youtube.com/watch?v=vjKX00jML64

Alternative video link https://archive.org/details/video_band_calc

First, **download the sample dataset**, which is a Landsat 8 image already converted to reflectance (see *Automatic Conversion to Surface Reflectance* (page 66)) from this link (data available from the U.S. Geological Survey). Also, **download the land cover classification** from here .

21.1 Application of a mask to multiple bands

Unzip the downloaded dataset and load all the raster bands in QGIS.

Open the *Band calc* (page 125) and click the button `Refresh list`.

We are going to use conditional expressions (i.e. `np.where`, for more information see this page) with the following structure:

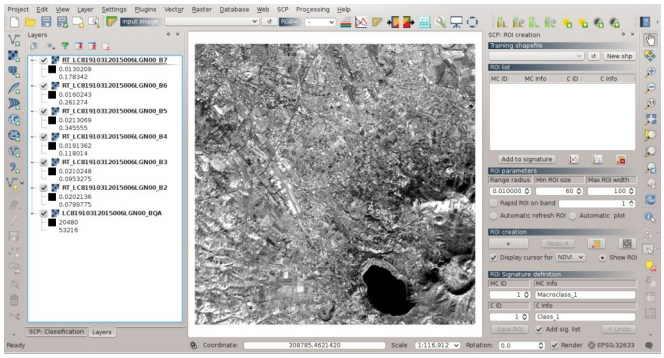


Fig. 21.1: *Bands loaded in QGIS*

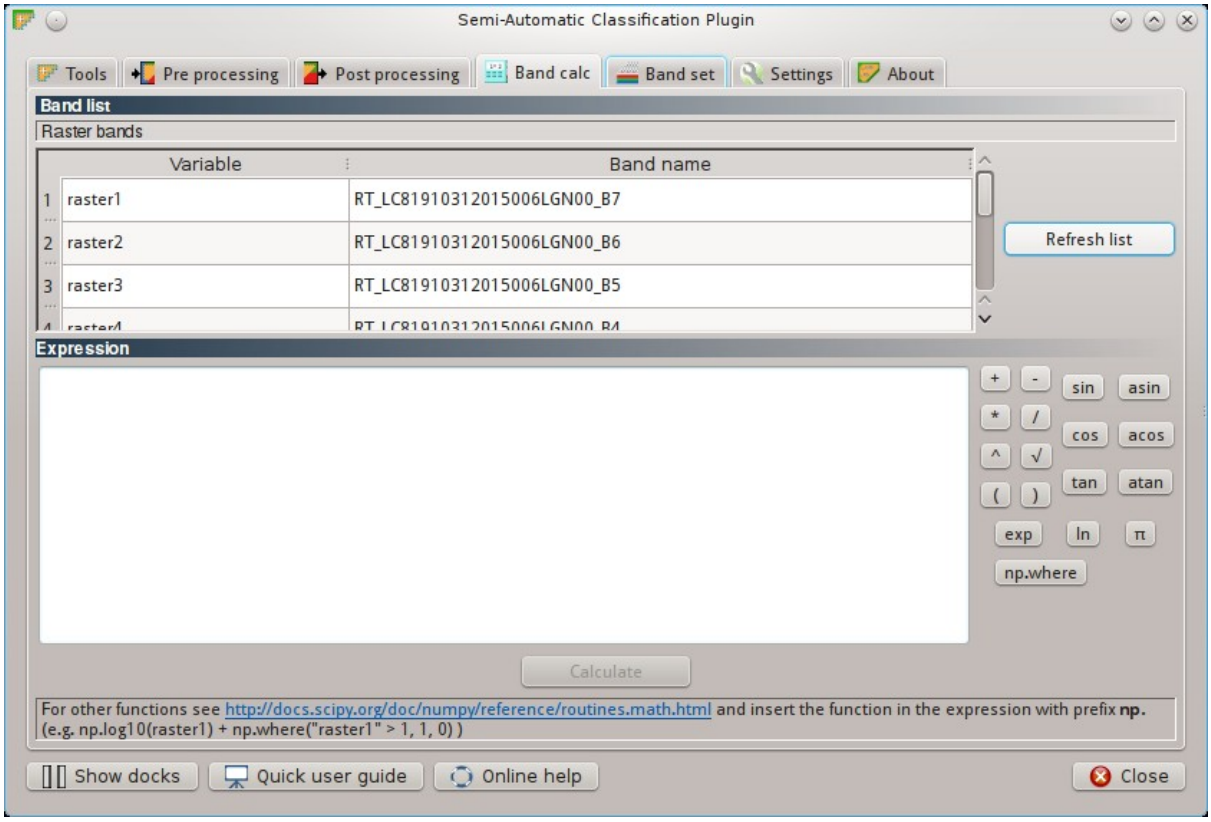


Fig. 21.2: *The Band calc tool*

```
np.where( condition , value if true, value if false)
```

Where:

- `condition` is a logical condition between bands or values;
- `value if true` and `value if false` can be a numerical value, a band, or another expression.

In `Expression` enter the following block of expressions:

```
np.where("LC81910312015006LGN00_BQA" == 53248, 0, "RT_LC81910312015006LGN00_B2")
np.where("LC81910312015006LGN00_BQA" == 53248, 0, "RT_LC81910312015006LGN00_B3")
np.where("LC81910312015006LGN00_BQA" == 53248, 0, "RT_LC81910312015006LGN00_B4")
np.where("LC81910312015006LGN00_BQA" == 53248, 0, "RT_LC81910312015006LGN00_B5")
np.where("LC81910312015006LGN00_BQA" == 53248, 0, "RT_LC81910312015006LGN00_B6")
np.where("LC81910312015006LGN00_BQA" == 53248, 0, "RT_LC81910312015006LGN00_B7")
```

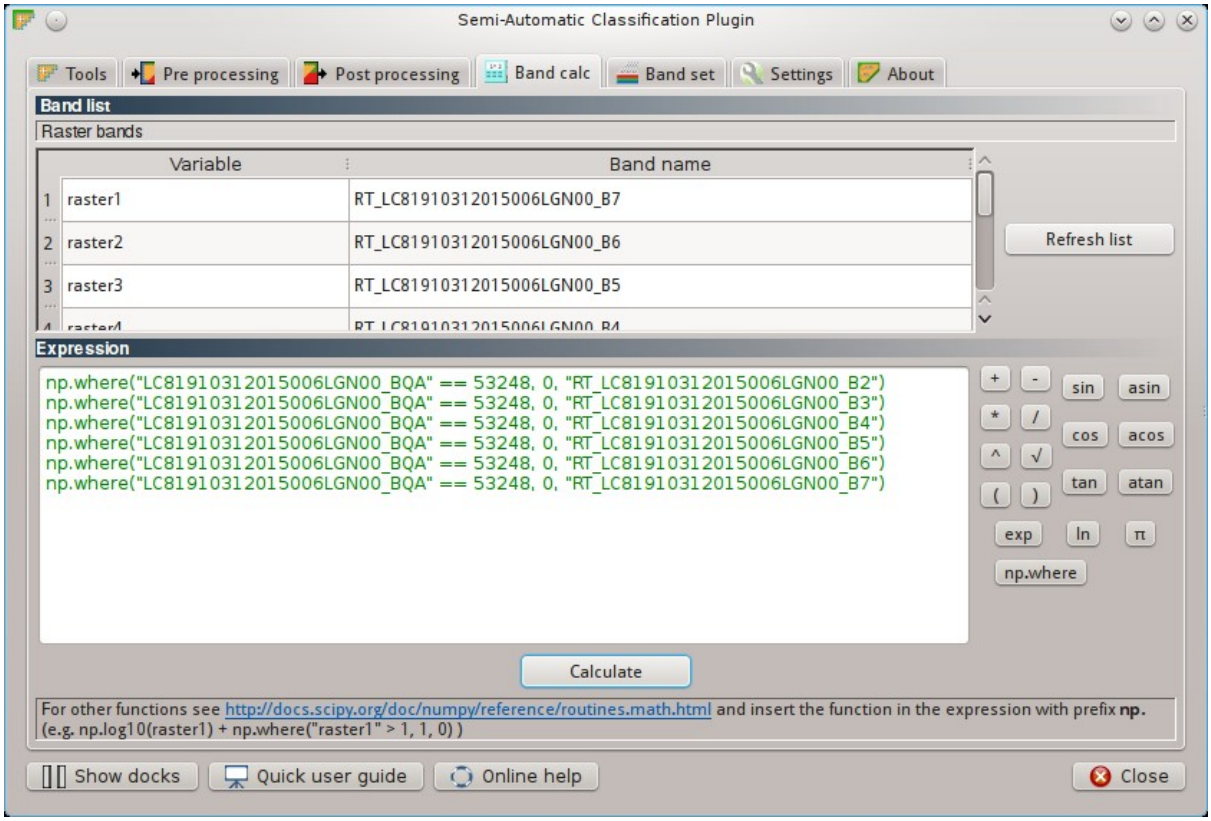


Fig. 21.3: *The expression in Band calc*

TIP : If the text in `Expression` is green it means that the syntax is correct, otherwise it is red and the button `Calculate` is disabled.

Click the button `Calculate`, select where to save the bands (e.g. a new directory named *masked_bands*) and write the output name (e.g. `masked`). Multiple outputs are created with the same output name and a numerical suffix based on the numerical order of the expressions. Calculated bands are also added to QGIS.

According to the order of expressions, the file `masked_1` corresponds to the band `RT_LC81910312015006LGN00_B2`, the file `masked_2` corresponds to the band `RT_LC81910312015006LGN00_B3`, and so on. Masked pixels have NoData values (i.e. nan).

21.2 NDVI Calculation

NDVI is an index calculated as `( Near Infrared band - Red band ) / (Near Infrared band + Red band)` which ranges from -1 to 1 . Green vegetation has the highest NDVI values tending to

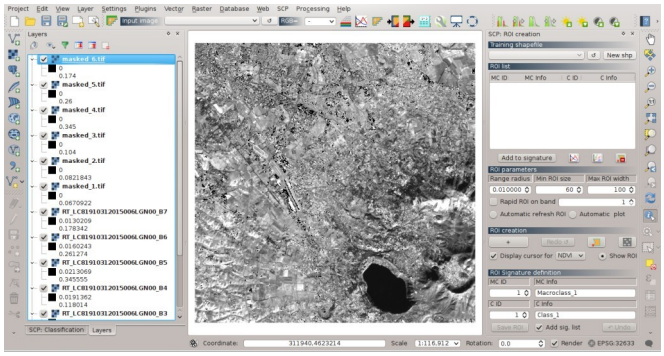


Fig. 21.4: *Masked bands*

1.

Open the *Band calc* (page 125) and click the button *Refresh list*. Clear the content of `Expression` and write the following expression for the calculation of NDVI:

```
("masked_4.tif" - "masked_3.tif") / ("masked_4.tif" + "masked_3.tif")
```

where `masked_4.tif` is the Near Infrared band and `masked_3.tif` is the Red band.

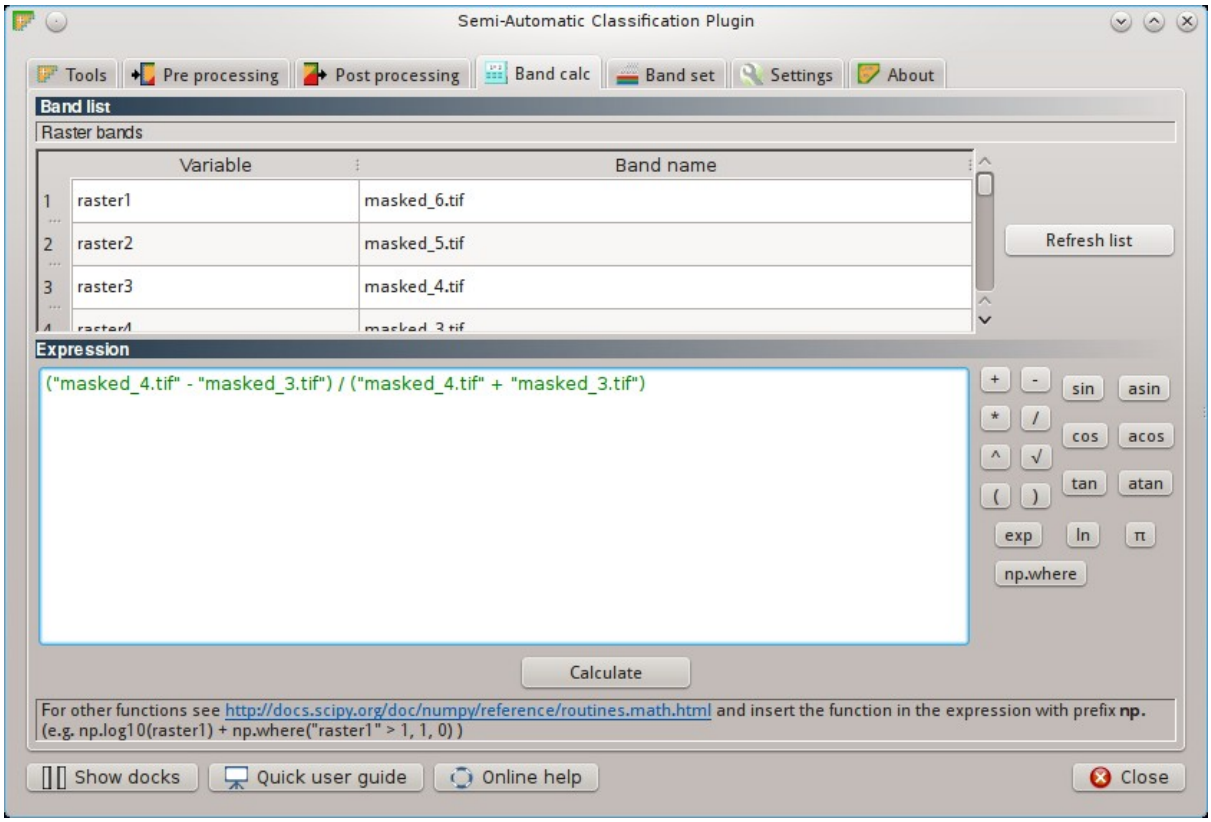


Fig. 21.5: *The expression in Band calc*

TIP : The expression can work both with `Variable` and `Band name` between quotes. Also, bands in the *Band set* (page 127) can be referenced directly; for example `bandset#b1` refers to band 1 of the Band set. Double click on any item in the *Band list* (page 126) for adding its name to the expression.

Click the button `Calculate`, select where to save the NDVI (e.g. a new file named *NDVI*). The NDVI is added to QGIS.

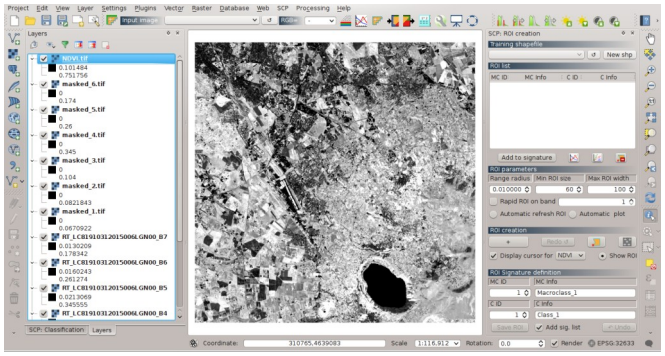


Fig. 21.6: *The NDVI calculated*

21.3 Classification refinement basing on NDVI values

Load the downloaded classification in QGIS.

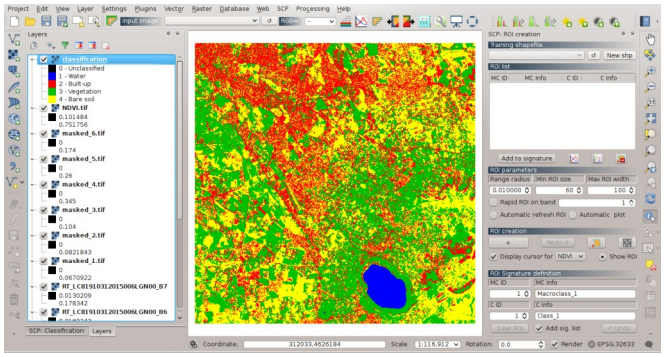


Fig. 21.7: *The land cover classification*

The classification is the result of *Tutorial 2: Land Cover Classification of Landsat Images* (page 65) where the land cover classes described in the following table were identified.

Class name	Pixel value
Water	1
Built-up	2
Vegetation	3
Bare soil	4

We are going to refine this classification defining the following condition: pixels having NDVI > 0.5 are classified Vegetation. The value 0.5 is an arbitrary value that should be changed according to the image condition (i.e. phenological state of vegetation).

Open the *Band calc* (page 125) and click the button *Refresh list*. Clear the content of `Expression` and write the following expression:

```
np.where("NDVI.tif" > 0.5, 3, "classification")
```

which means that if NDVI value is greater than 0.5, assign the pixel value 3 (i.e. Vegetation), otherwise leave the original classification value.

Click the button `Calculate`, select where to save the new classification (e.g. a new file named `refined_classification`). The new classification is added to QGIS.

It is possible to copy the style from the original classification (in QGIS Layers right click on the layer name and select `Copy style`) and paste it to the new classification (right click on the layer name and select `Paste style`).

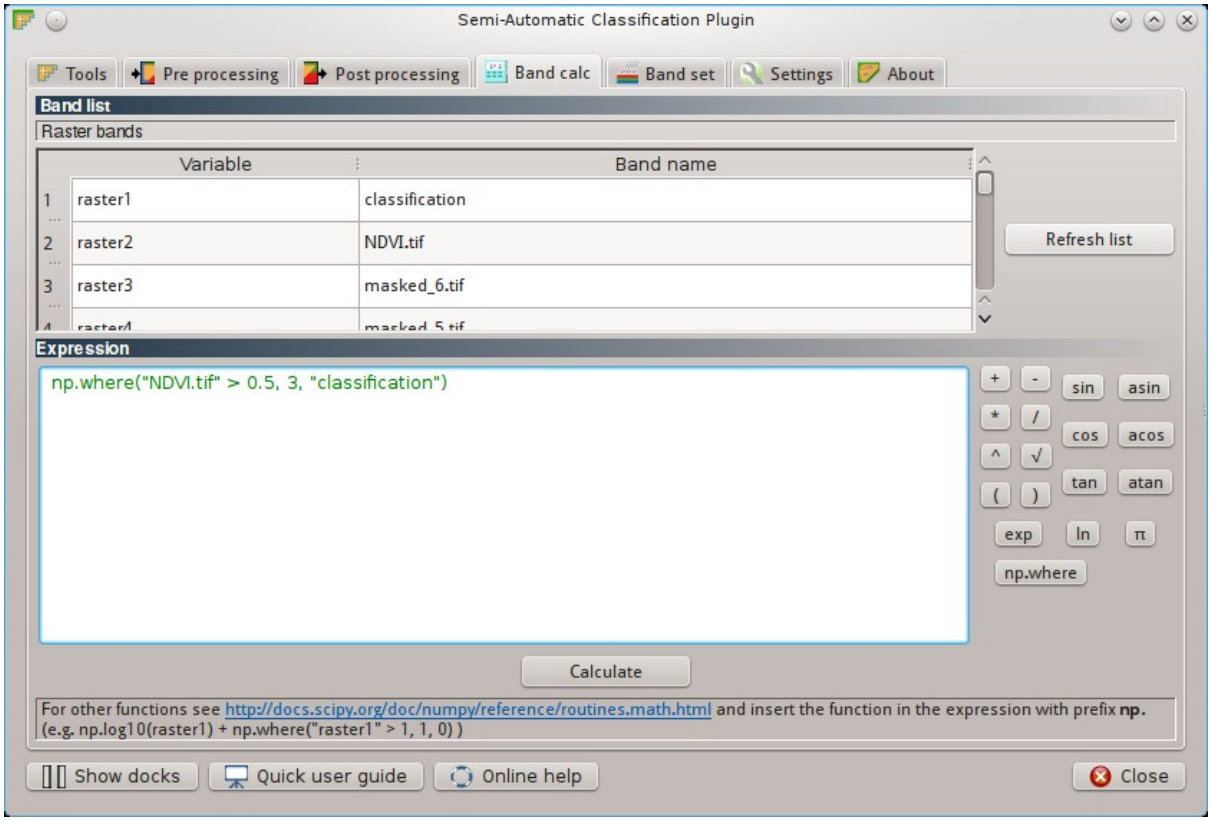


Fig. 21.8: *The expression in Band calc*

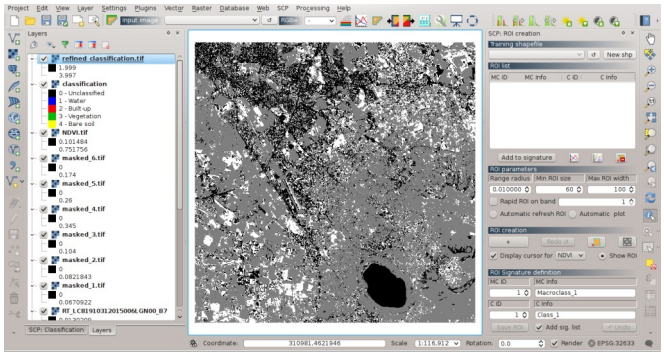


Fig. 21.9: *The output land cover classification*

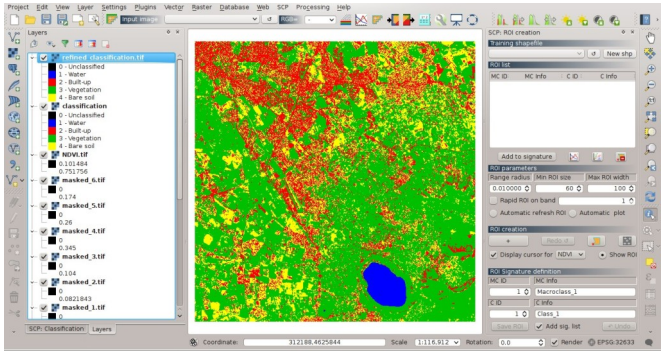


Fig. 21.10: *The output land cover classification with color style*

You can see that now a larger area is classified as vegetation.

CHAPTER 22

Other Tutorials

Visit the blog From GIS to Remote Sensing for other tutorials such as:

- Supervised Classification of Hyperspectral Data;
- Monitoring Deforestation;
- Flood Monitoring;
- Estimation of Land Surface Temperature with Landsat Thermal Infrared Band;
- Land Cover Classification of Cropland.

For other unofficial tutorials, also in languages other than English, see *Where can I find more tutorials about SCP, also in languages other than English?* (page 211).

Part VI

Semi-Automatic OS

The Semi-Automatic OS is a lightweight virtual machine for the land cover classification of remote sensing images. It includes the Semi-Automatic Classification Plugin for QGIS, already configured along with all the required dependencies.

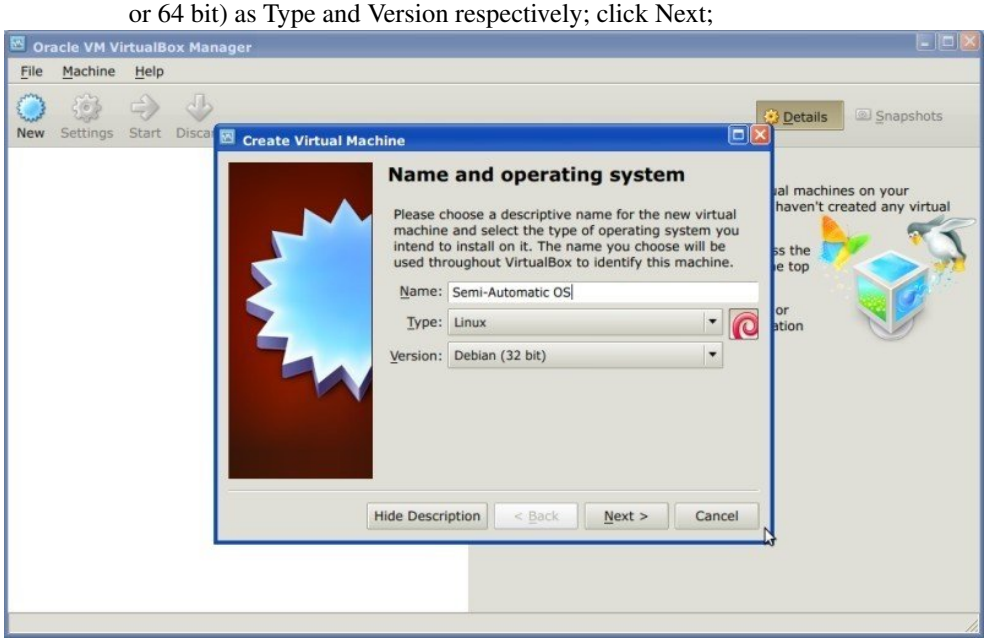
Fig. 22.1: *Semi-Automatic OS desktop*

The Semi-Automatic OS is based on Debian , and it is designed to require very little hardware resources. It uses LXDE and Openbox as main desktop environment. This virtual machine can be useful for testing the Semi-Automatic Classification Plugin, or when the installation of the required programs in the host system is problematic.

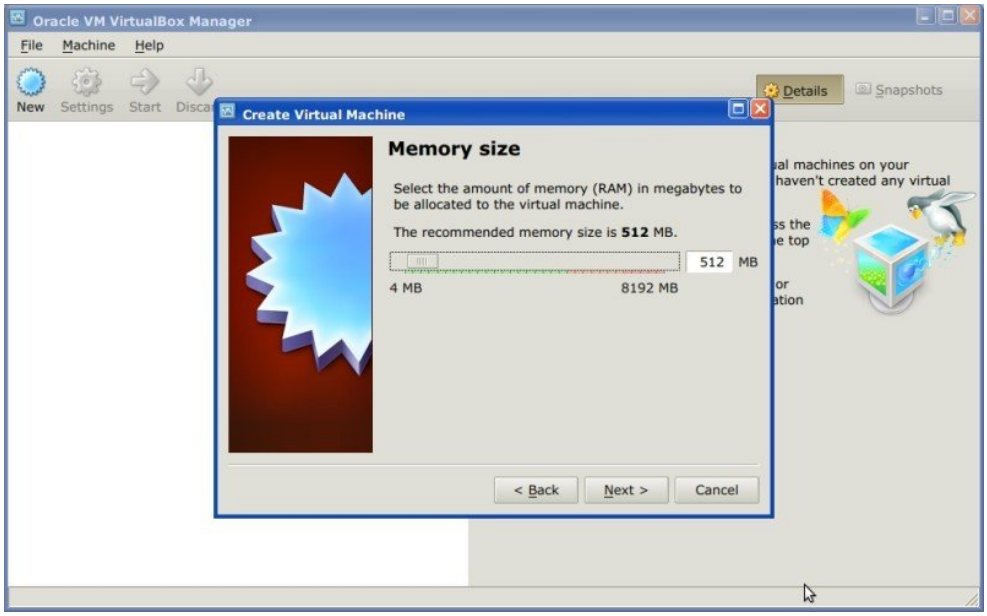
The Semi-Automatic OS is available as a 32 bit and 64 bit virtual machine that can be run in the open source VirtualBox, or any other virtualization program. The following is a guide for the installation of the Semi-Automatic OS in the open source program of virtualization VirtualBox.

Installation in VirtualBox

1. Download VirtualBox open source software (select a proper version depending on your OS) and install it; at the end of the installation restart the system;
2. Download the Semi-Automatic OS virtual machine (about 600 MB) from here (32 bit or 64 bit);
3. Extract the virtual machine content in a directory (it requires about 3 GB of disk space); the file is compressed in 7z format (if needed, download the open source extraction software from http://www.7-zip.org/);
4. Run VirtualBox and create a new Debian virtual machine;
   (a) Click the New button;
   (b) Type a name for the virtual machine (for instance Semi-Automatic OS); select Linux and Debian (32 or 64 bit) as Type and Version respectively; click Next;



   (c) Set the memory size; the more is the better, but this parameter should not exceed a half of he host system RAM (for instance if the host system has 1 GB of RAM, type 512 MB); click Next;

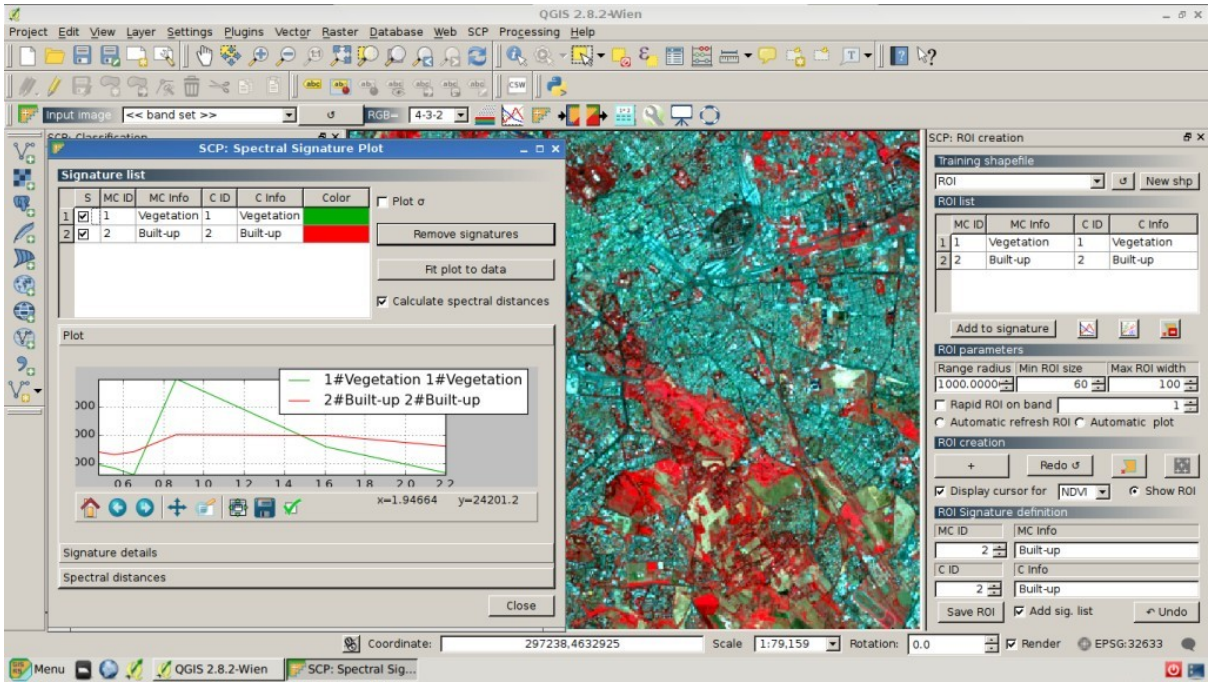


(d) In the Hard drive settings select Use an existing virtual hard drive file and select the downloaded file SemiAutomaticOS.vmdk; click Create;

Oracle VM VirtualBox Manager
File
Machine
Help
New
Settings
Start
Details
Snapshots
Create Virtual Machine
Hard drive
If you wish you can add a virtual hard drive to the new machine. You can either create a new hard drive file or select one from the list or from another location using the folder icon.
If you need a more complex storage set-up you can skip this step and make the changes to the machine settings once the machine is created.
The recommended size of the hard drive is 10,00 GB.
Do not add a virtual hard drive
Create a virtual hard drive now
Use an existing virtual hard drive file
Semi-Automatic OS.vmdk (Normal, 10,00 G
< Back
Create
Cancel

5. Start the Semi-Automatic OS by clicking the Start button;
6. It is recommended to install the virtualbox-guest-utils in the virtual machine, from the Menu > Preferences > Synaptic Package Manager; it allows for a better integration of the Semi-Automatic OS in the host system, such as: the resize of the system window, or the folder sharing.

The Semi-Automatic OS includes a sample dataset (Landsat 8 images available from the U.S. Geological Survey) that can be used for testing purposes.



Semi-Automatic OS is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, version 3 of the License. Semi-Automatic OS is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details. See http://www.gnu.org/licenses/.

Part VII

Frequently Asked Questions

- *Plugin installation* (page 201)
  - *How to install the plugin manually?* (page 201)
- *Pre processing* (page 203)
  - *Which image bands should I use for a semi-automatic classification?* (page 203)
  - *Which Landsat bands can be converted to reflectance by the SCP?* (page 203)
  - *Can I apply the Landsat conversion and DOS correction to clipped bands?* (page 203)
  - *Can I apply the DOS correction to Landsat bands with black border (i.e. with NoData value)?* (page 203)
  - *How to remove cloud cover from Landsat images?* (page 204)
  - *How do I create a virtual raster manually in QGIS?* (page 204)
- *Tutorials* (page 205)
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- *Errors* (page 207)
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  - *Error [26] 'The version of Numpy is outdated'. Why?* (page 208)
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- *Other* (page 211)
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  - *Where can I ask a new question?* (page 211)
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  - *How can I translate this user manual to another language?* (page 212)

This is a collection of Frequently Asked Questions. For other questions please visit From GIS to Remote Sensing FAQ

CHAPTER 24

Plugin installation

24.1 How to install the plugin manually?

In order to install the plugin manually:

1. download the zip file from the QGIS Python Plugins Repository;
2. open the directory `.qgis2/python/plugins` that is inside the User/Home directory and delete the folder SemiAutomaticClassificationPlugin if present;
3. extract the downloaded zip file inside the directory `.qgis2/python/plugins`;
4. the plugin should be installed; start QGIS, open the Plugin Manager and be sure that Semi-Automatic Classification Plugin is checked.

CHAPTER 25

Pre processing

25.1 Which image bands should I use for a semi-automatic classification?

In general, it is preferable to avoid thermal infrared bands. If you are using Landsat 4, 5 or 7 you should select bands: 1, 2, 3, 4, 5, 7 avoiding band 6 that is thermal infrared; for Landsat 8 you should select bands: 2, 3, 4, 5, 6, 7.

25.2 Which Landsat bands can be converted to reflectance by the SCP?

All Landsat 1,2, and 3 MSS and Landsat 4, 5, 7, and 8 images downloaded from http://earthexplorer.usgs.gov/ and processed with the Level 1 Product Generation System (LPGS) can be converted to reflectance automatically by the SCP; products generated by the LPGS have a MTL file included that is required for the conversion. Since version 3.1.1 the SCP can also convert images from the Global Land Cover Facility (images available for free from ftp://ftp.glcf.umd.edu/glcf/Landsat/). In particular, images having an old format of the MTL file (or a .met file) can be processed through the automatic conversion to reflectance and the DOS correction. However, some images do not have the required information and cannot be processed. Also, notice that some images available from the Global Land Cover Facility are already converted to reflectance. For this process, image bands must be renamed in order to remove the final 0 if present (e.g. rename B10 to B1).

25.3 Can I apply the Landsat conversion and DOS correction to clipped bands?

Yes, you can clip the images before the conversion to reflectance and then copy the MTL file (contained in the Landsat dataset) inside the directory with the clipped bands. If you want to apply the DOS correction (which is an image based technique) you should convert the original Landsat bands (the entire image) and then clip the conversion output (i.e. bands converted to reflectance).

25.4 Can I apply the DOS correction to Landsat bands with black border (i.e. with NoData value)?

If you want to apply the DOS correction to an entire Landsat band which has NoData values (the black border with value = 0) then you have to check the checkbox `Use NoData value` and set the value to 0. This is because DOS is an image based technique, and NoData values must be excluded from the calculation.

25.5 How to remove cloud cover from Landsat images?

DOS1 correction does not remove clouds from the image. However, Landsat 8 images include Band 9 that identifies clouds (see this NASA site). You can use this band for the creation of a mask.

For other Landsat satellites, clouds can be masked using the approach described this paper.

Also, see the following video-tutorial.

25.6 How do I create a virtual raster manually in QGIS?

In order to create a multi-spectral virtual raster in QGIS:

1. from the menu `Raster` select `Miscellaneous > Build Virtual Raster (catalog);`
2. click the button `Select...` and select all the Landsat bands (in numerical order);
3. select the output file (for instance `rgb.vrt`); check `Separate` (bands will be separated) and click `OK`.

CHAPTER 26

Tutorials

26.1 Why using only Landsat 8 band 10 in the estimation of surface temperature?

There are several methods for estimating surface temperature. The method described in this tutorial requires only one band and can be applied also to Landsat 5 and 7. Moreover, USGS recommends that users refrain from relying on Landsat 8 Band 11 data in quantitative analysis of the Thermal Infrared Sensor data (see Changes to Thermal Infrared Sensor (TIRS) data by USGS).

CHAPTER 27

Errors

27.1 How can I report an error?

If you found an error of the Semi-Automatic Classification Plugin please follow these steps in order to collect the required information (log file):

1. close QGIS if already open;
2. open QGIS, open the Plugin tab *Settings: Debug* (page 132) and check the checkbox `Records events in a log file` ;

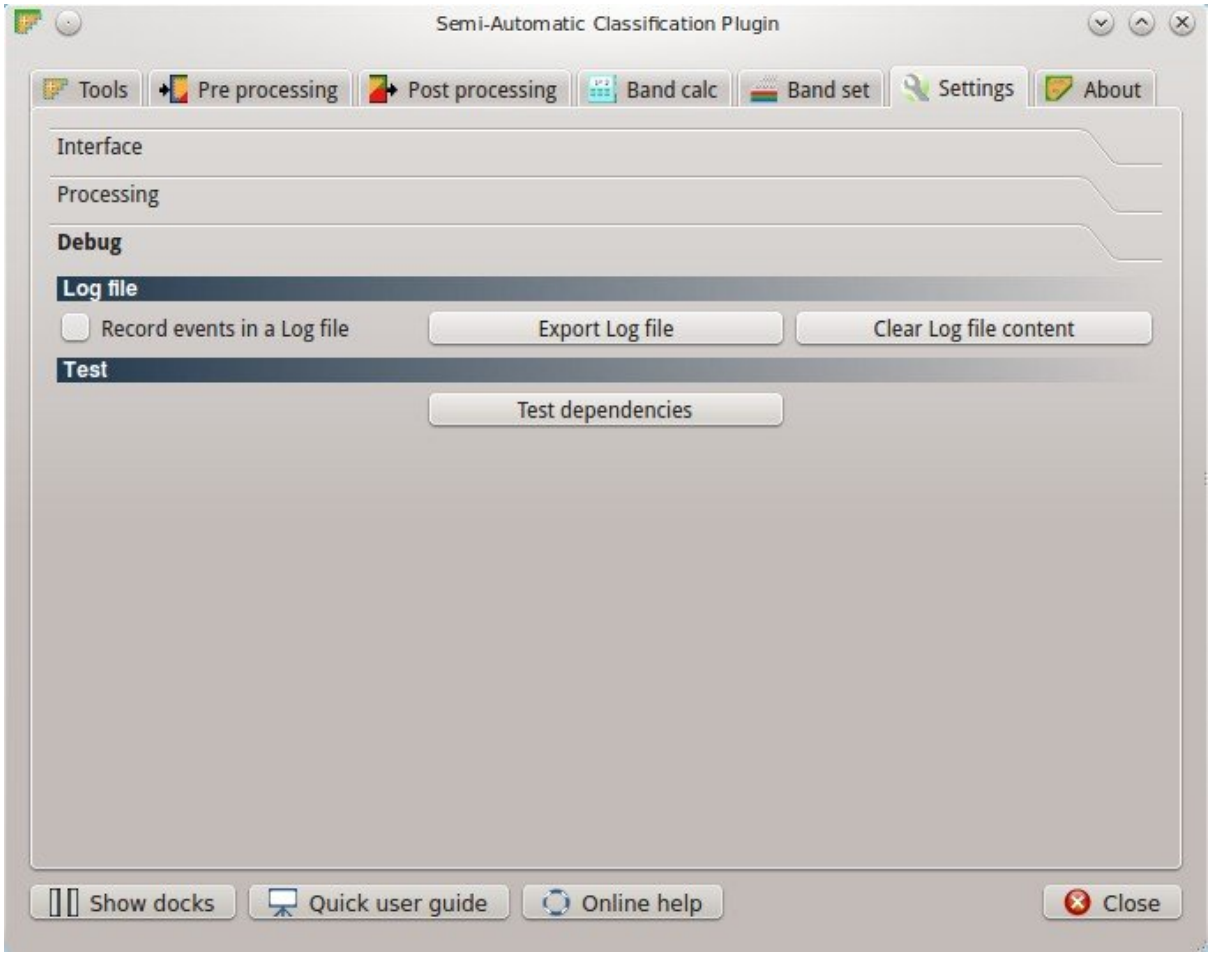

Fig. 27.1: *Debug*

3. click the button `Test dependencies` in the tab *Settings: Debug* (page 132) ;

4. **load the data in QGIS (or open a previously saved QGIS project) and repeat all the steps that cause the error in the Pl**

    - if the issue could be related to the image data, please use this sample dataset ;

5. if an error message appears (like the one in the following image), copy the whole content of the message in a text file;

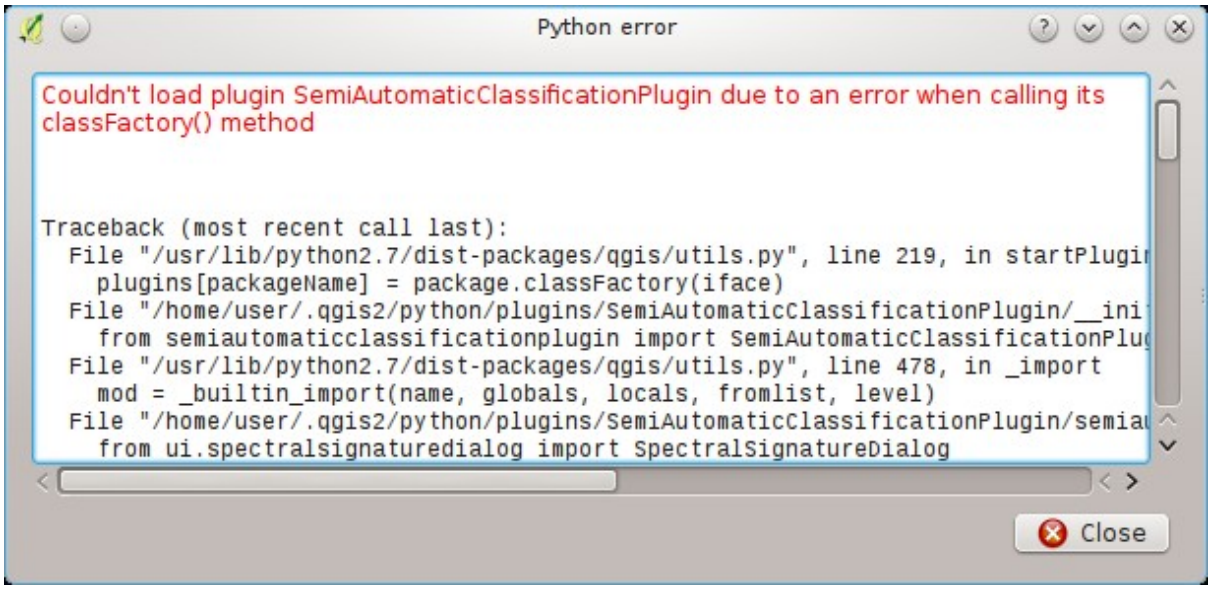
Python error
Couldn't load plugin SemiAutomaticClassificationPlugin due to an error when calling its classFactory() method
Traceback (most recent call last):
File "/usr/lib/python2.7/dist-packages/qgis/utils.py", line 219, in startPlugi
plugins[packageName] = package.classFactory(iface)
File "/home/user/.qgis2/python/plugins/SemiAutomaticClassificationPlugin/__ini
from semiautomaticclassificationplugin import SemiAutomaticClassificationPlu
File "/usr/lib/python2.7/dist-packages/qgis/utils.py", line 478, in _import
mod = _builtin_import(name, globals, locals, fromlist, level)
File "/home/user/.qgis2/python/plugins/SemiAutomaticClassificationPlugin/semia
from ui.spectralsignaturedialog import SpectralSignatureDialog
Close

Fig. 27.2: *Error message*

6. open the tab *Settings: Debug* (page 132) and uncheck the checkbox `Records events in a log file`, then click the button `Export Log file` and save the **log file** (which is a text file containing information about the Plugin processes);
7. open the **log file** and copy the whole content of the file;
8. join the Facebook group or the Google+ community , create a new post and copy the error message and the **log file** (or attach them).

27.2 Why am I having issues during the creation of the Landsat virtual raster?

The automatic creation of the virtual raster after Landsat conversion to reflectance is not required for the classification. Errors could happen if the output destination path contains special characters (such as accented letters) or spaces; try to rename directories (e.g. rename `new directory` to `new_directory`). If you still get the same error you can create a virtual raster manually.

27.3 Error [26] 'The version of Numpy is outdated'. Why?

QGIS 32bit could have an older version of Numpy as default; in order to update Numpy:

1. download this file (which is based on WinPython installer and PyParsing);
2. extract the file with 7-zip;
3. copy the content of the extracted directory inside the directory `apps\Python27\Lib\site-packages` inside the QGIS installation directory (e.g. `C:\Program Files (x86)\QGIS Chugiak\apps\Python27\Lib\site-packages`) overwriting the files `pyparsing`, `numpy`, `matplotlib`, and `scipy`.

Alternatively, you should be able to install QGIS and Numpy with the OSGEO4W advanced installer.

27.4 Error 'Plugin is damaged. Python said: ascii'. Why?

It could be related to a wrong installation. Please, uninstall QGIS and install it again with administrative rights. Delete also the directory .qgis2 in your user directory. Then run QGIS 2 and try to install the plugin following the *Plugin Installation* (page 5) guide.

Also, it could be related to the user name containing special characters. Please try the installation creating a new user without special characters (e.g. `user`).

Also, if the error message contains something like: `sfnt4 = sfnt4.decode('ascii').lower()`

it could be related to a known issue of Matplotlib (a Python library); in order to solve this, you should (as reported at stackoverflow):

1. open in a text editor the file font_manager.py which is inside the directory `C:\PROGRA~1\QGISCH~1\apps\Python27\lib\site-packages\matplotlib\`
2. **search for the line** `sfnt4 = sfnt4.decode('ascii').lower()`
3. **and replace it with the line** `sfnt4 = sfnt4.decode('ascii', 'ignore').lower()`

Alternatively, try to install QGIS through the OSGEO4W installer, which includes an updated Matplotlib version.

CHAPTER 28

Other

28.1 What are free and valuable resources about remote sensing and GIS?

The following links are remote sensing and Landsat images:

- The Landsat 8 Data Users Handbook by USGS;
- The Landsat 7 Science Data Users Handbook by NASA;
- Remote Sensing Note by JARS.

28.2 Where can I ask a new question?

A Facebook group and a Google+ Community are available for sharing information and asking for help.

28.3 Where can I find more tutorials about SCP, also in languages other than English?

There are several tutorials about SCP on the internet. Following an incomplete list of these resources:

- French: Suivre l'impact des feux de forêts par imagerie satellite avec le plugin Qgis SCP;
- German: 2015 Jakob Erfassung von Landnutzungsveränderungen mit FOSS Image Processing Tools;
- Italian: Classificazione e Mosaico di Varie Immagini Landsat;
- Korean: QGIS Semi-Automatic Classification Plugin;
- Portuguese: Classificação Supervisionada de Imagens Orbitais com o Semi-Automatic Classification Plugin;
- Portuguese: Tutorial Classificação e caracterização de imagens de satélites;
- Portuguese: Aprendizagem Supervisionada usando o SCP no QGIS;
- Portuguese: Classificação supervisionada utilizando o QGIS e SCP;
- Spanish: Ejercicio Clasificación Semiautomática Plugin (SCP);
- Spanish: Aplicaciones de Teledetección con el QGIS y el plugin Semi-Automatic Classification;
- Spanish: Descarga de Landsat 8, 7, 5 y 4 Semi Automatic Classification Plugin Qgis 2.8;
- Swedish: Landsat 8 och fjärranalys med QGIS;
- Ukrainian: ;

28.4 How can I translate this user manual to another language?

It is possible to easily translate the user manual to any language, because it is written in reStructuredText as markup language (using Sphinx). Therefore, your contribution is fundamental for the translation of the manual to your language. The following guide illustrates the main steps for the translation, which can be performed:

- using the free online service Transifex;
- using the gettext .po files.

Method 1. Translation using the free online service Transifex

This is probably the easiest way to translate the manual using an online service.

1. Transifex free registration

   Go to the Transifex login page (https://www.transifex.com/signin/). You can sign in using your Google or Facebook account, or with a free registration.

2. Join the Semi-automatic Classification Manual project

   Go to the page https://www.transifex.com/semi-automatic-classification/semi-automatic-classification-plugin-4-manual/ . Select your language and click the button Join team. If your language is not listed, click the button Request language.

3. Translation

   There are several files to be translated, which refer to the sections of the SCP manual. The translation is performed through an online application, which shows you each sentence in the original English version, and a text editor allows for the translation to your language. This should make the translation process very rapid and easy.

Method 2. Translation using the gettext .po files

In order to use this method, you should be familiar with GitHub. This translation method allows for the translation of the PO files locally.

1. Download the translation files

   Go to the GitHub project https://github.com/semiautomaticgit/SemiAutomaticClassificationManual_v4/tree/master/local and download the .po files of your language (you can add your language, if it is not listed), or you can fork the repository. Every file .po is a text file that refers to a section of the User Manual.

2. Edit the translation files

   Now you can edit the .po files. It is convenient to edit those file using one of the following programs: for instance Poedit for Windows and Mac OS X, or Gtranslator for Linux or OmegaT (Java based) for Windows, Linux and Mac OS X. These editors allow for an easy translation of every sentence in the User Manual.